A STORY OF THE GALACTIC CENTER GAMMA-RAY EXCESS

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OUTLINE

- Introduction to the Galactic Center Excess (GCE)
  - Brief background and characteristics
- Dark matter vs pulsars?
  - How to tell hypotheses apart
  - Latest developments
- Understanding systematics
  - Subtleties behind GCE analyses
- Ways forward

2008:
FERMI LAUNCHES

THE FERMI TELESCOPE

- Sensitive to gamma rays
  ~300 MeV to few TeV

- Full-sky field of view,
  in low-Earth orbit (340 miles)

- Publicly available data!

2009:

INNER GALAXY EXCESS FOUND

2009:
INNER GALAXY EXCESS FOUND

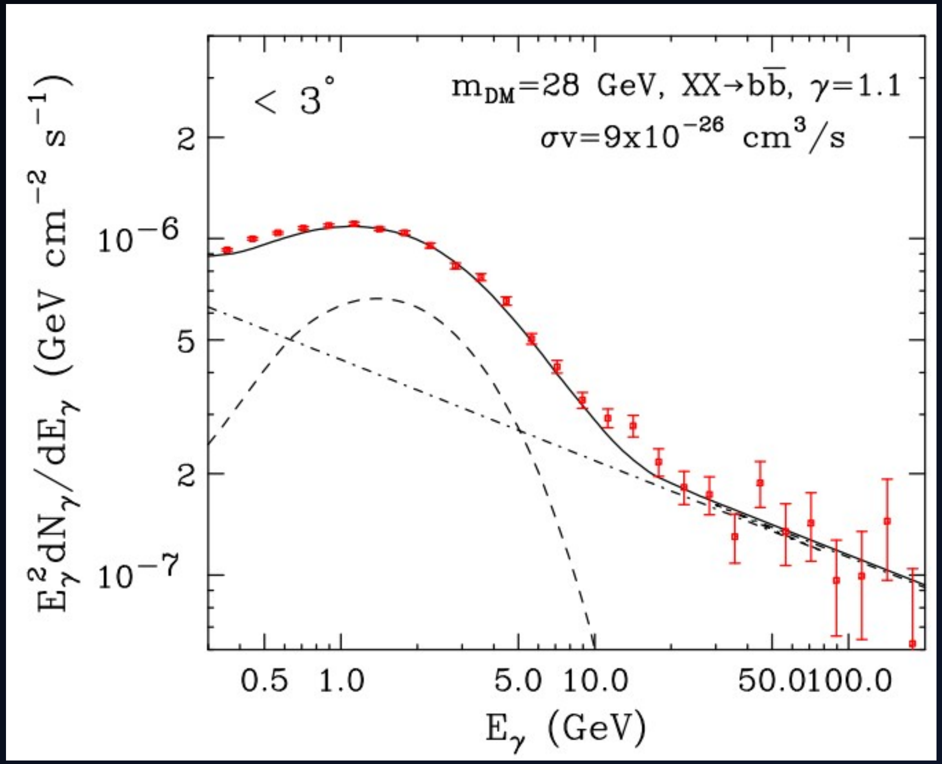
Possible Evidence For Dark Matter Annihilation In The Inner Milky Way From The Fermi Gamma Ray Space Telescope

Lisa Goodenough[1] and Dan Hooper[2,3]

[1] *Center for Cosmology and Particle Physics, Department of Physics, New York University, New York, NY 10003*
[2] *Center for Particle Astrophysics, Fermi National Accelerator Laboratory, Batavia, IL 60510*
[3] *Department of Astronomy and Astrophysics, University of Chicago, Chicago, IL 60637*

THE GALACTIC CENTER GEV EXCESS

- Identified by Dan Hooper and Lisa Goodenough
- Highly significant bright excess in gamma rays
- Peaked at 1-3 GeV

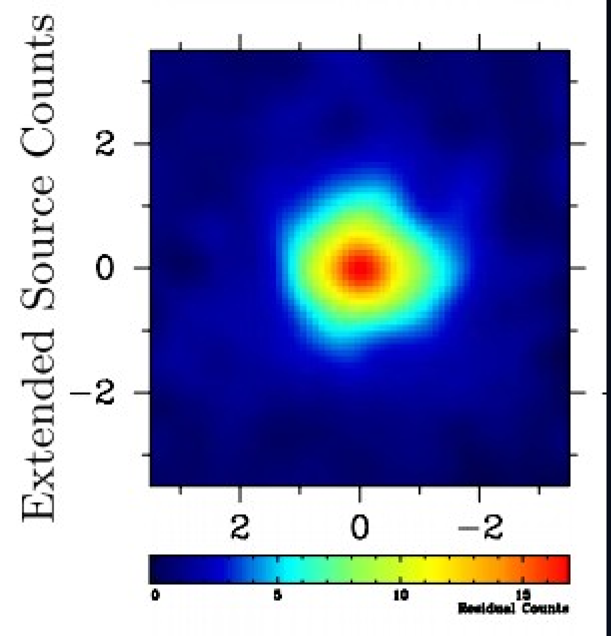


Goodenough+Hooper '09

2010-14:
CLUES OF ITS PROPERTIES

Rebecca Leane

MORPHOLOGY



Abazajian+ Kaplinghat ‘12

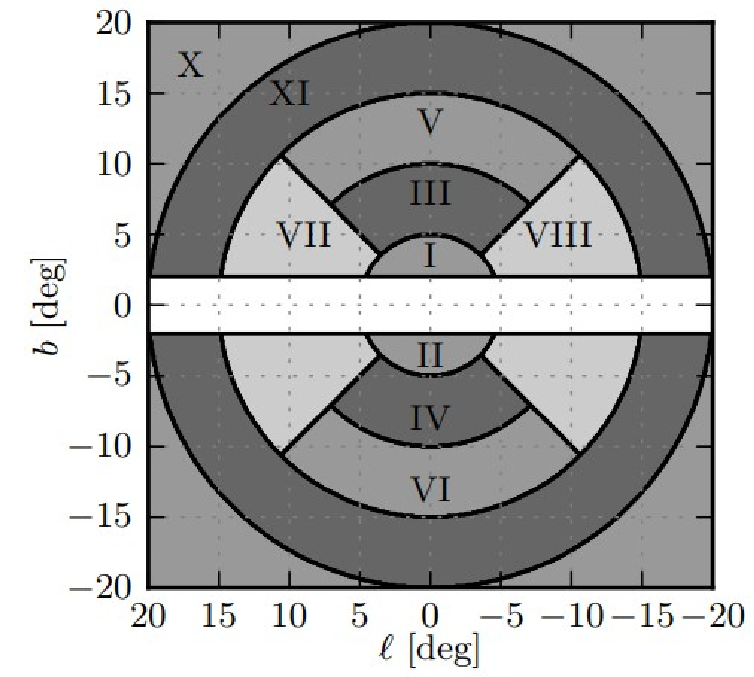
Spherically symmetric around Galactic Center

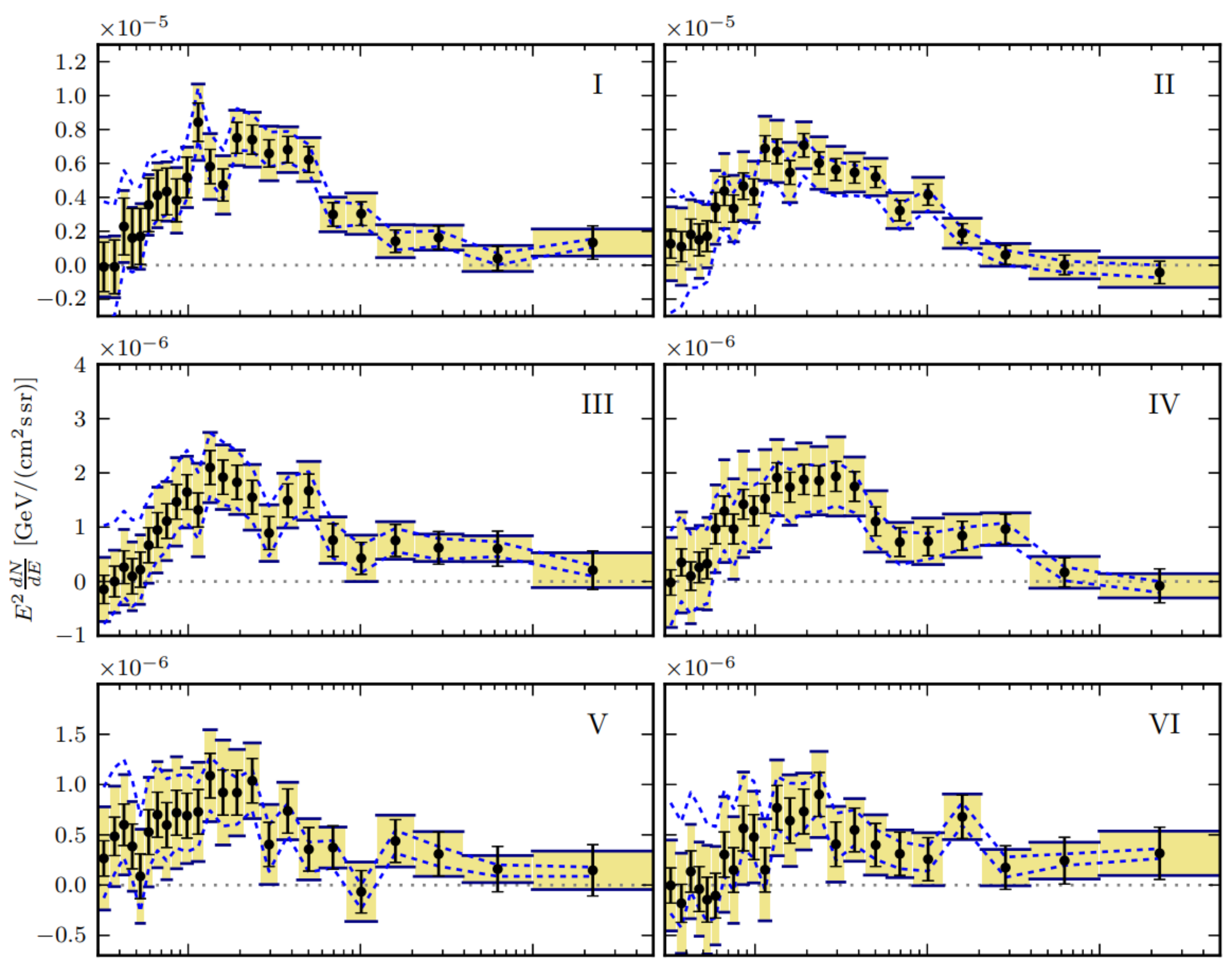
Scales like $r^{-2.4}$ extending out to around 10°, roughly fits standard dark matter (NFW) profile

Hooper+Slatyer ‘13

SPECTRUM

- Shape appears to be uniform throughout the Inner Galaxy



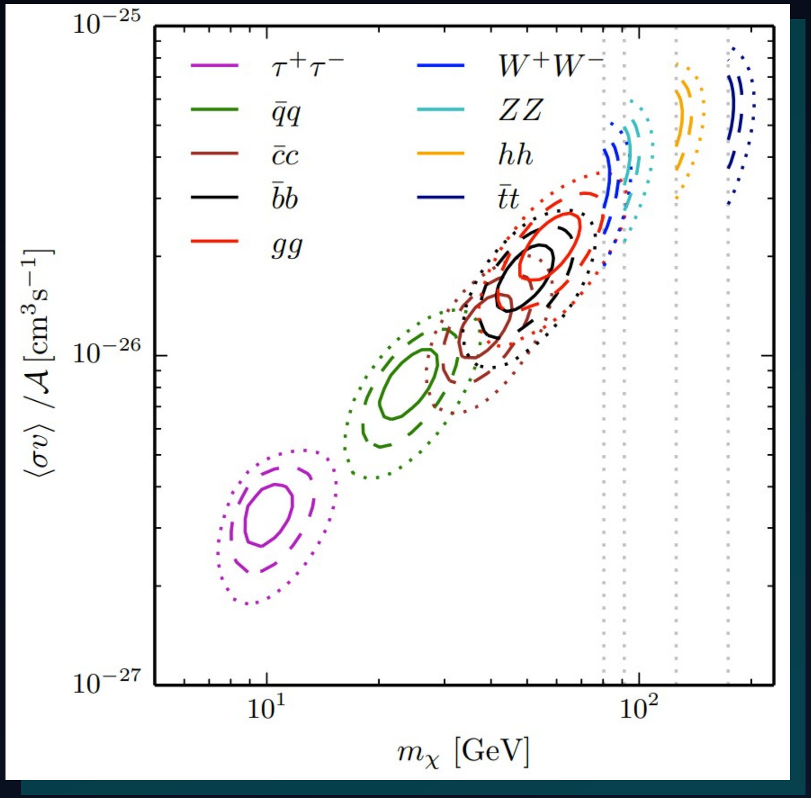


Calore et al '14

INTENSITY+SPECTRUM

Spectrum well fit by a ~20-60 GeV dark matter particle annihilating to hadronic final states

…with the intensity expected of thermal particle dark matter



Calore et al ‘14

SIGNAL OF ANNIHILATING DARK MATTER?

- Morphology consistent?
  - approximately spherical
  - extending well out of the center

- Intensity of thermal particle dark matter
  - can match thermal relic annihilation cross section

- Spectrum consistent: invariant with position and shape

If dark matter, first evidence of DM – SM interactions:
want to get to the bottom of this!

2014:
A COMPELLING CASE FOR DARK MATTER

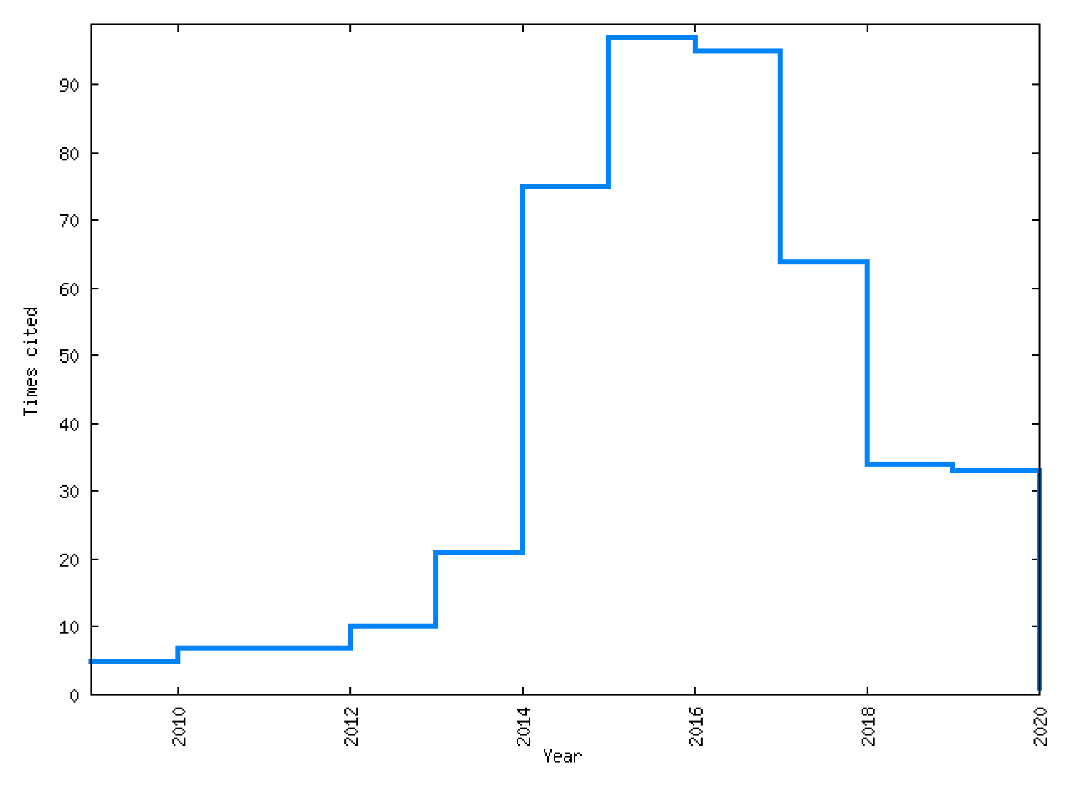
2014:
A COMPELLING CASE FOR DARK MATTER

The Characterization of the Gamma-Ray Signal from the Central Milky Way: A Compelling Case for Annihilating Dark Matter

Tansu Daylan,[1] Douglas P. Finkbeiner,[1,2] Dan Hooper,[3,4] Tim Linden,[5]
Stephen K. N. Portillo,[2] Nicholas L. Rodd,[6] and Tracy R. Slatyer[6,7]

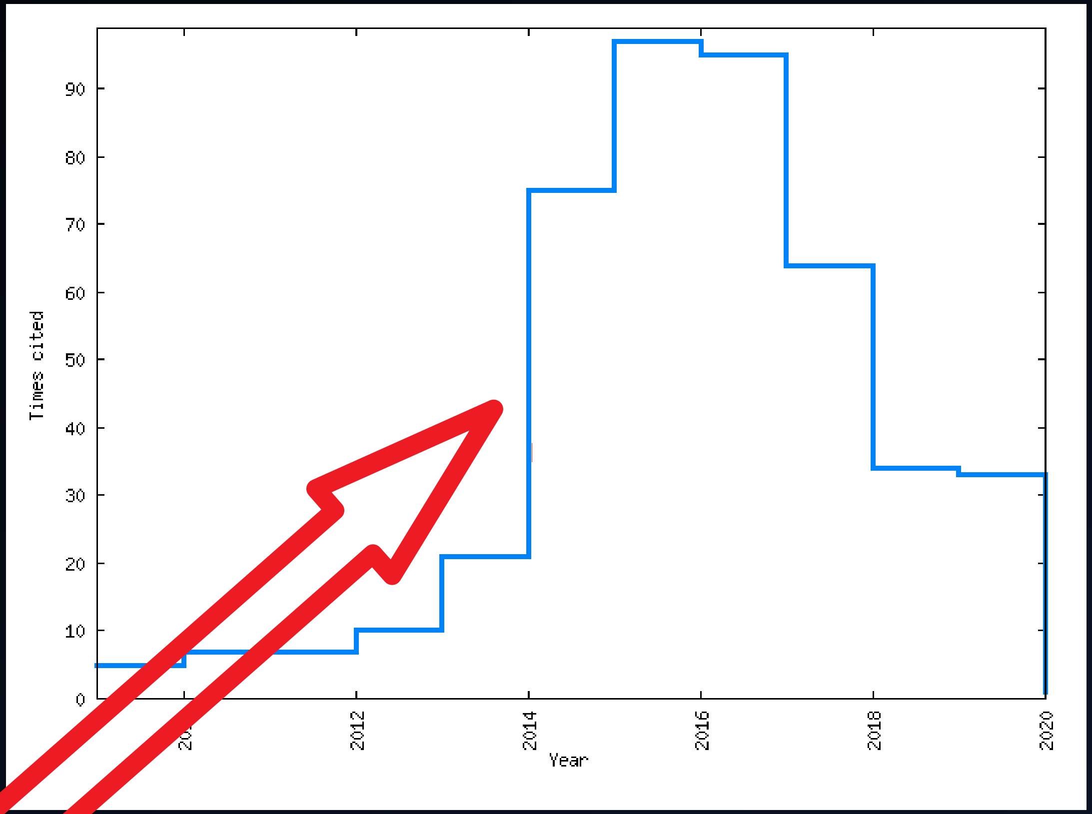
[1] *Department of Physics, Harvard University, Cambridge, MA*
[2] *Harvard-Smithsonian Center for Astrophysics, Cambridge, MA*
[3] *Fermi National Accelerator Laboratory, Theoretical Astrophysics Group, Batavia, IL*
[4] *University of Chicago, Department of Astronomy and Astrophysics, Chicago, IL*
[5] *University of Chicago, Kavli Institute for Cosmological Physics, Chicago, IL*
[6] *Center for Theoretical Physics, Massachusetts Institute of Technology, Boston, MA*
[7] *School of Natural Sciences, Institute for Advanced Study, Princeton, NJ*

HOOPER+GOODENOUGH CITATIONS



Inspire-HEP, citations per year

HOOPER+GOODENOUGH CITATIONS



"Compelling case for DM" comes out

Inspire-HEP, citations per year

2015

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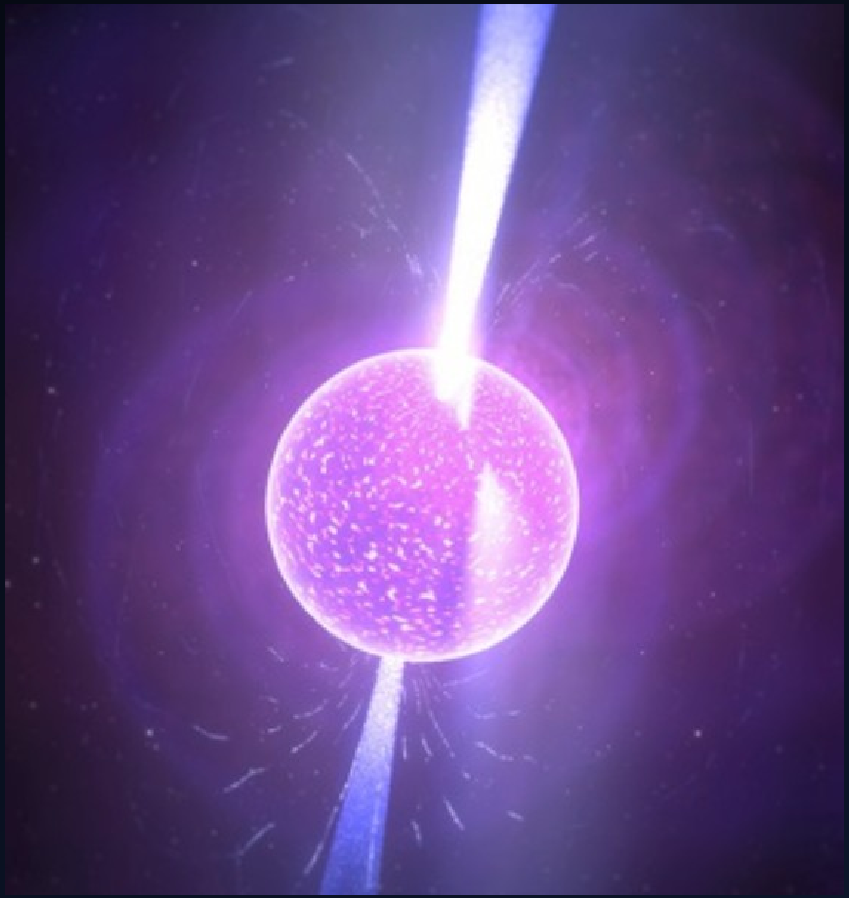
PULSARS AS THE EXCESS

- Pulsars are rapidly spinning neutron stars

- Pulsars also match the gamma-ray energy spectrum

- Pulsars appear as point sources to Fermi, which mean they have angular extent below detector thresholds



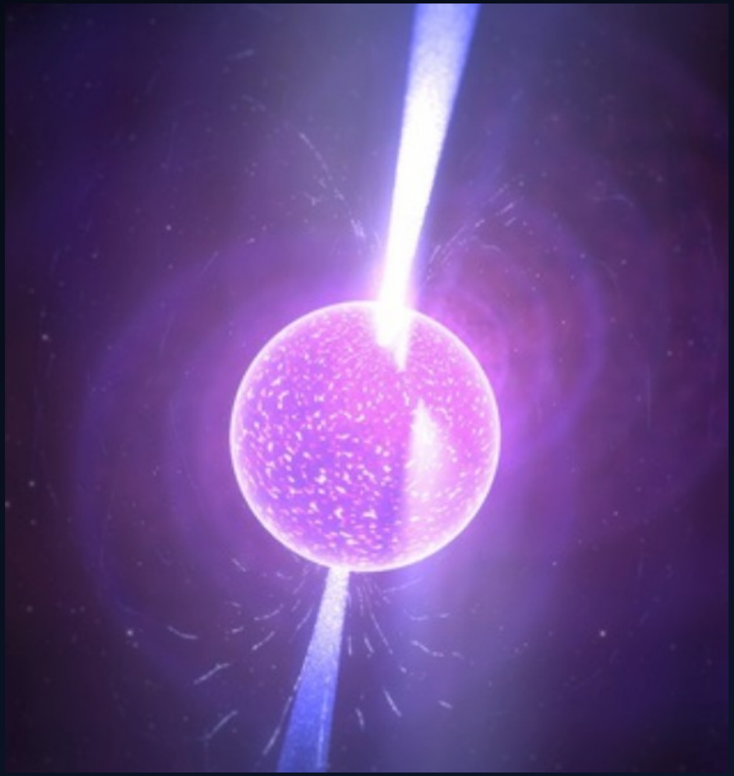
POINT SOURCES AS THE EXCESS

- Resolved Point Sources:

  Bright enough to be individually detected

- Unresolved Point Sources:

  Too dim to be individually detected, cannot be individually resolved, but collectively could explain GCE

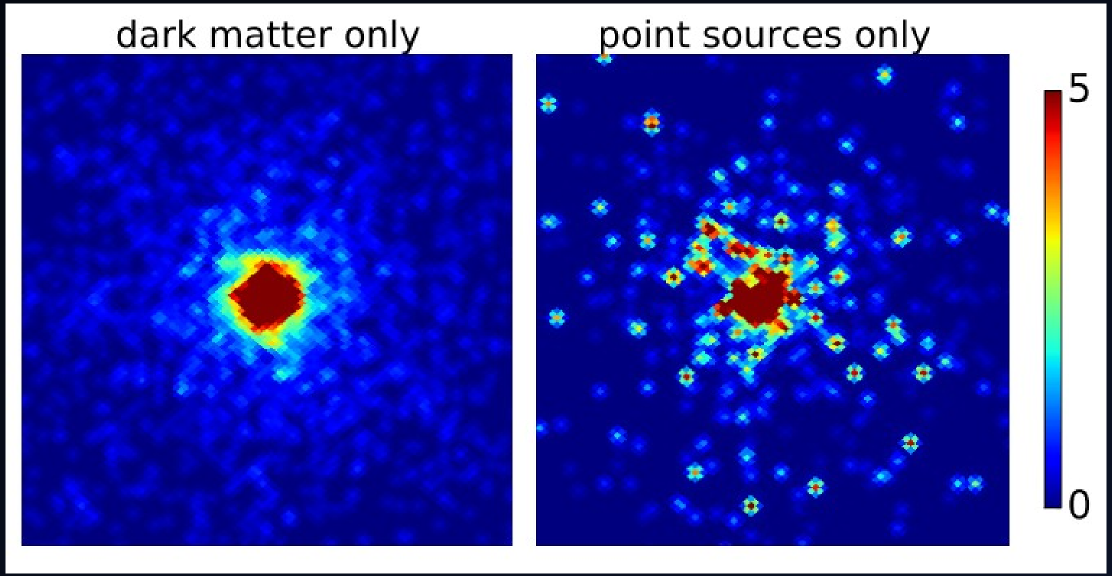


DISTINGUISHING DM vs. POINT SOURCES

Counts of gamma rays from point sources exhibit different statistical behavior compared to those from annihilating DM:

Lee+ '15

Dark matter: smooth continuous halo in the Galaxy



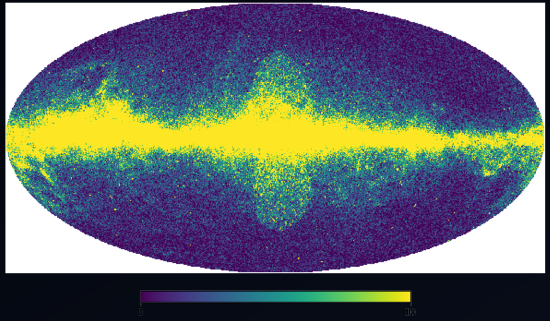
Point Sources: clumpy individual sources

Poisson

Non- Poissonian

METHOD 1: TEMPLATE FITTING

Full sky



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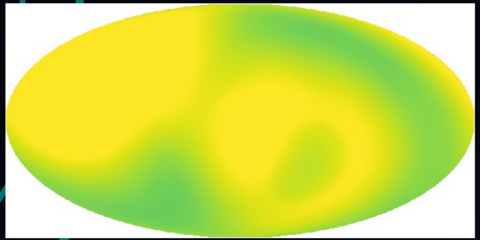
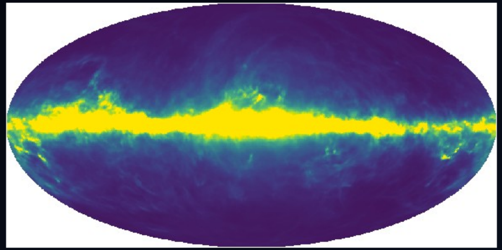
(Example combination)



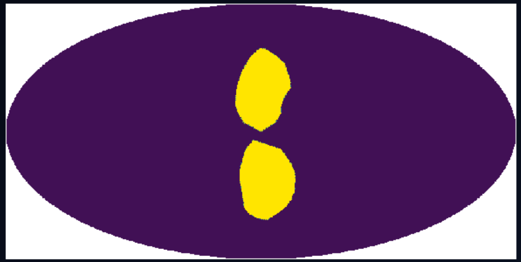
Isotropic

+



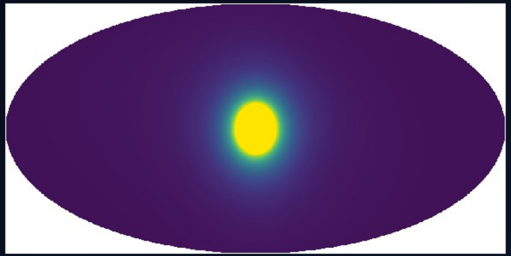
Diffuse

+



Bubbles

+

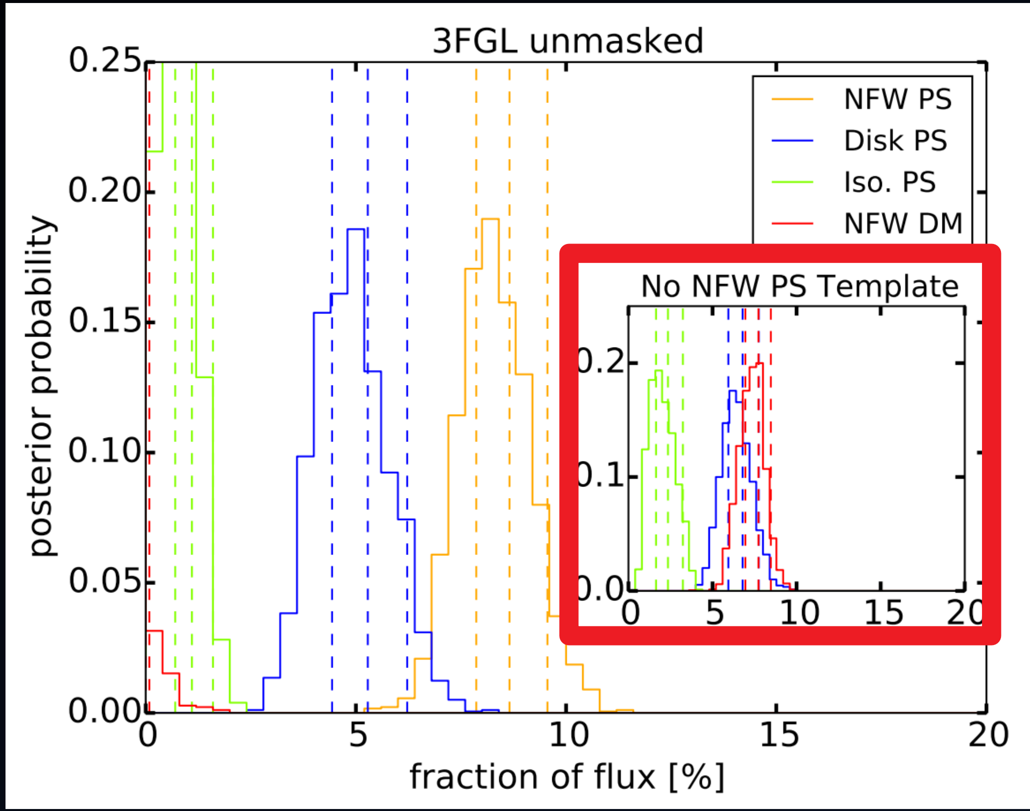


GCE

Build up picture of gamma ray sky by modeling individual components

Allow all components, or "templates" to float, see if smooth or clumpy is preferred for the GCE template (Lee+ '15)

EVIDENCE FOR POINT SOURCES AT THE GALACTIC CENTER



Lee, Lisanti, Safdi, Slatyer, Xue (PRL ‘15)

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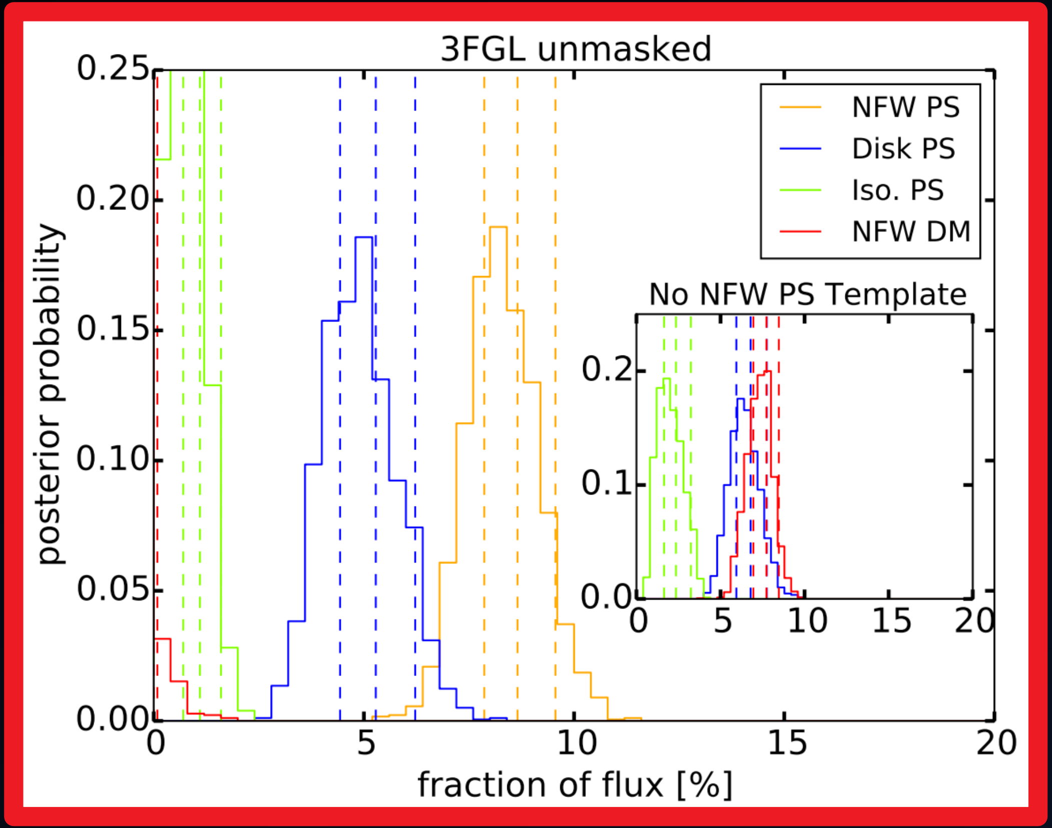

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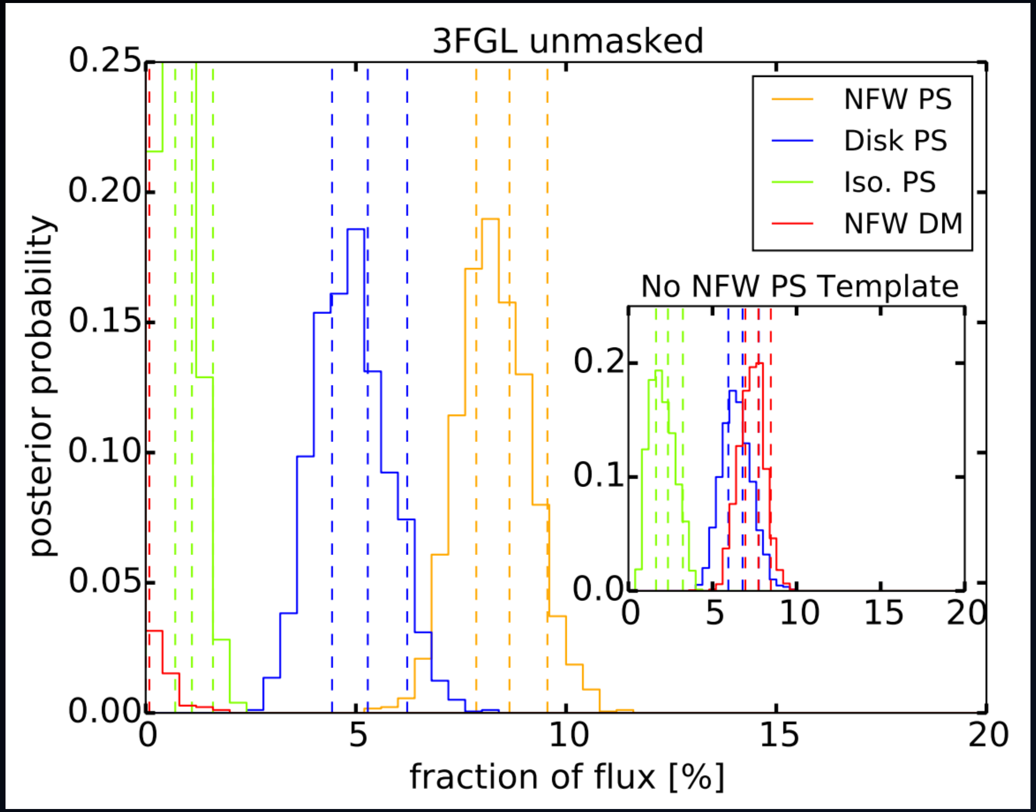

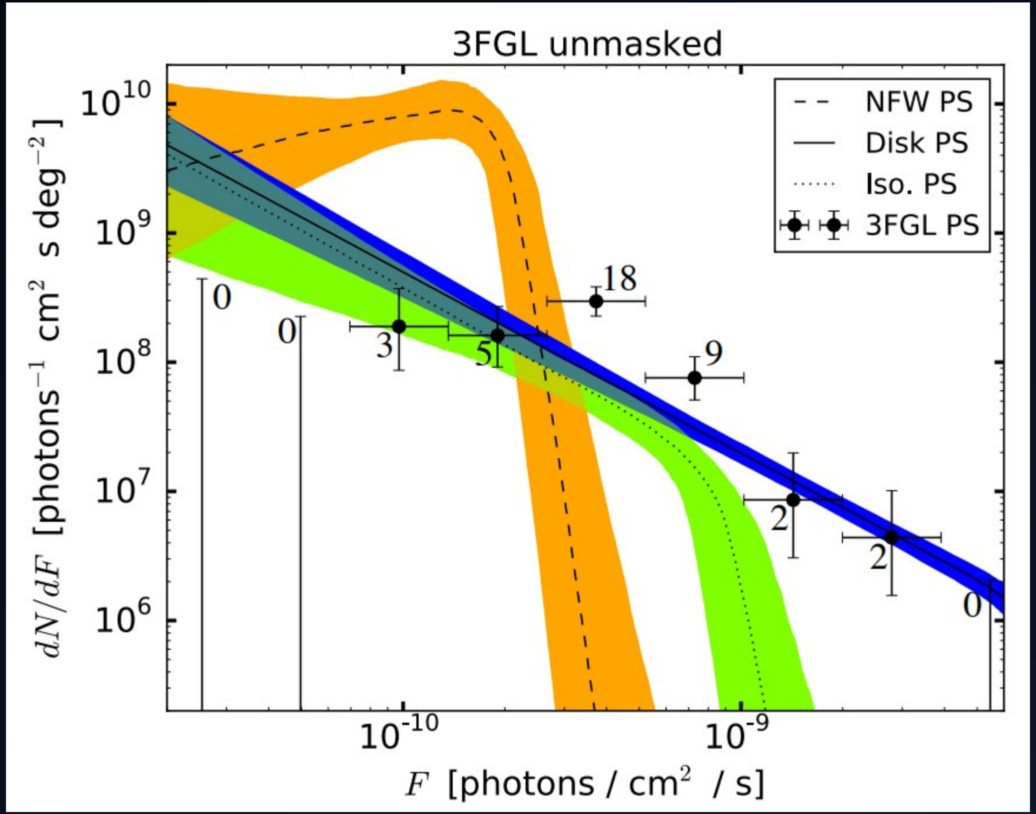

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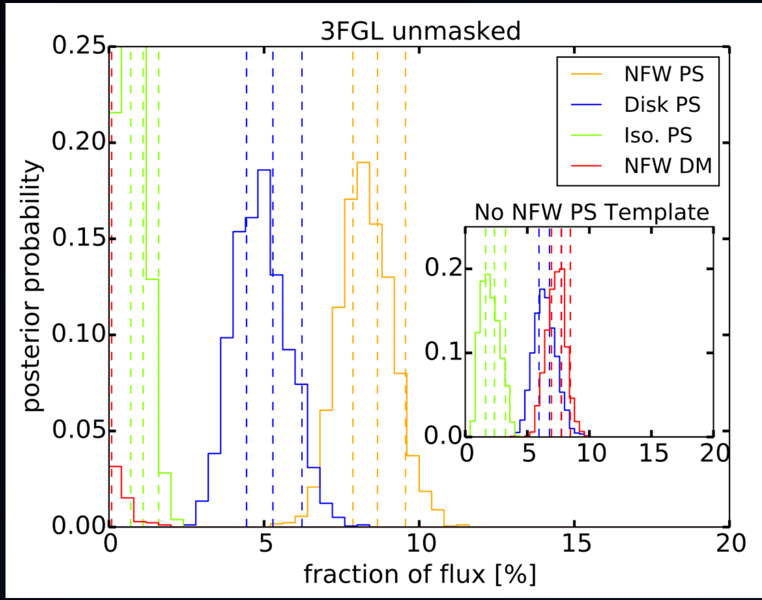


Lee, Lisanti, Safdi, Slatyer, Xue (PRL '15)

2.

Also in 2015...

METHOD 2: WAVELETS

Use wavelet transform to look for peaks in the data

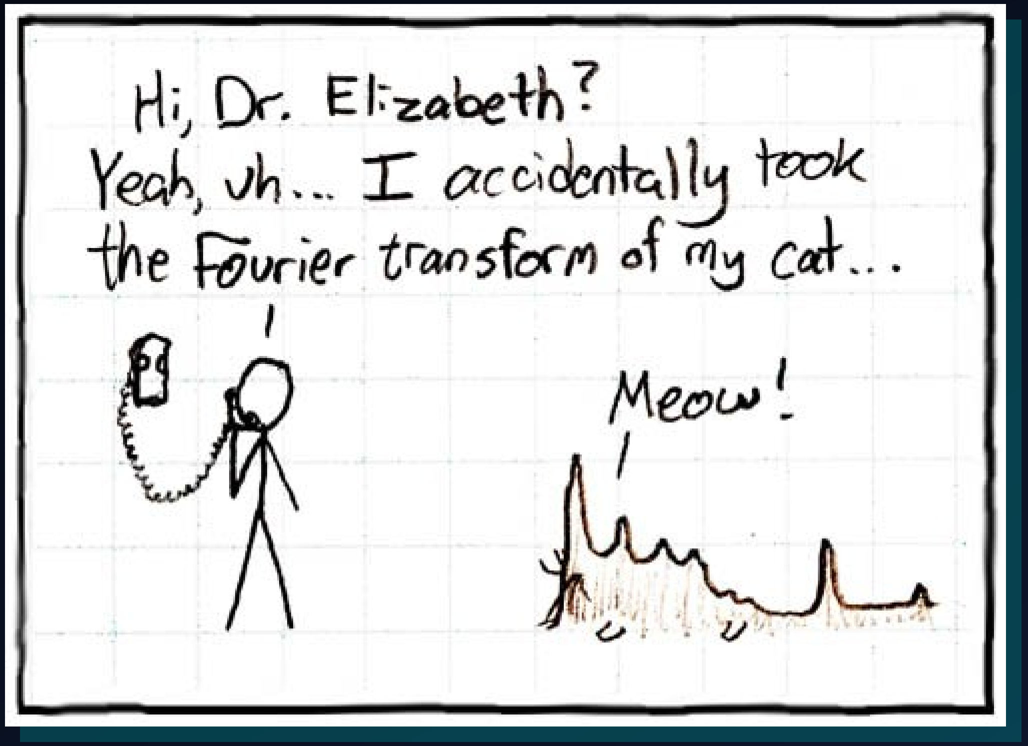
As before,

Clumpy (peaks):

point sources

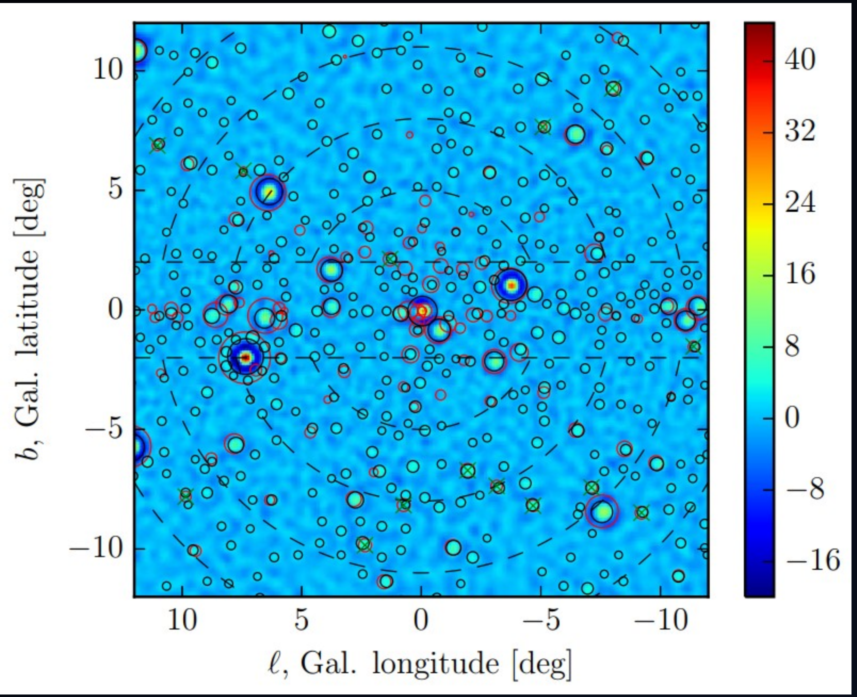
Smooth (no peaks):

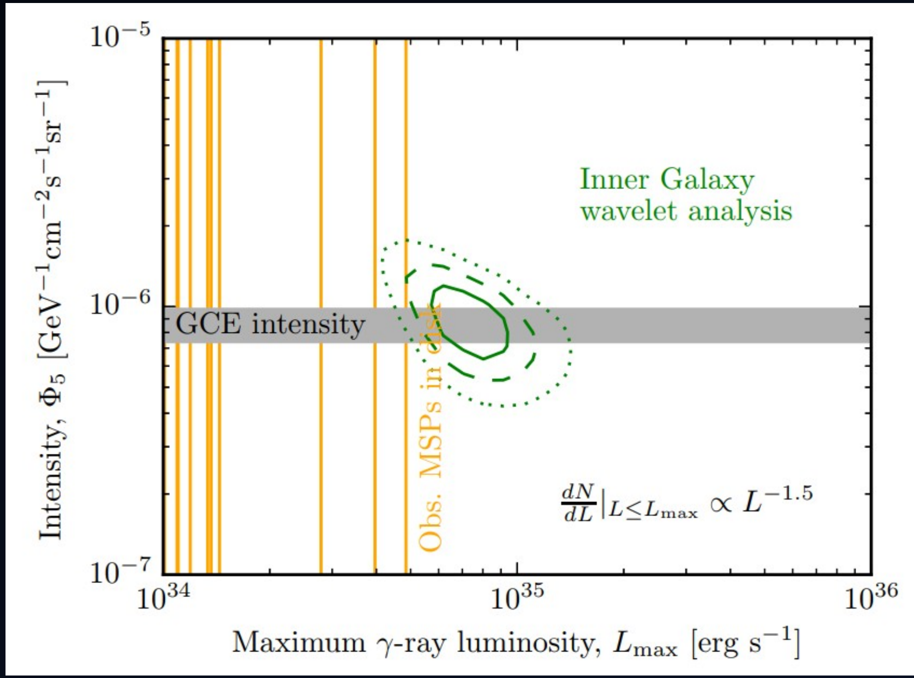
either no point sources,
or very faint point sources



xkcd

WAVELET METHOD: AGREEMENT



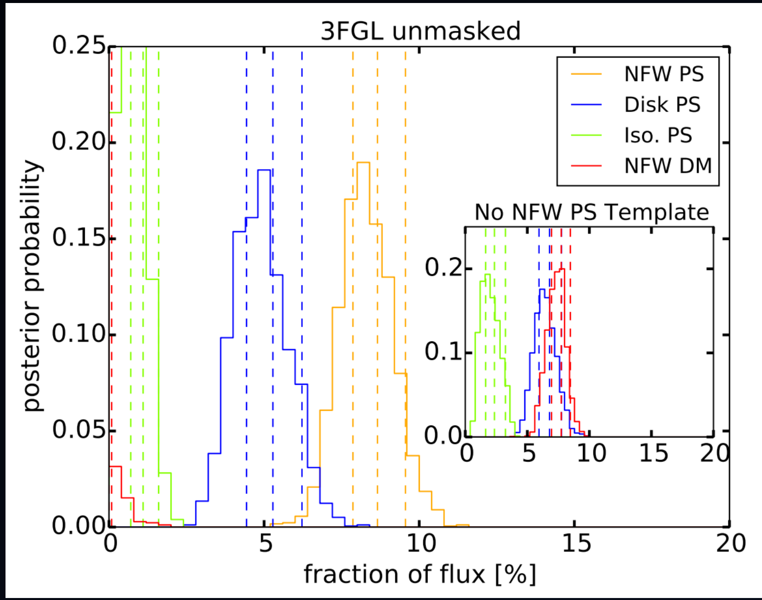


Detection of clustering of photons, consistent with a
new population of millisecond pulsars with the intensity of excess

Bartels, Krishnamurthy, Weniger (PRL ’15)

EVIDENCE FOR POINT SOURCES AT THE GALACTIC CENTER

1.



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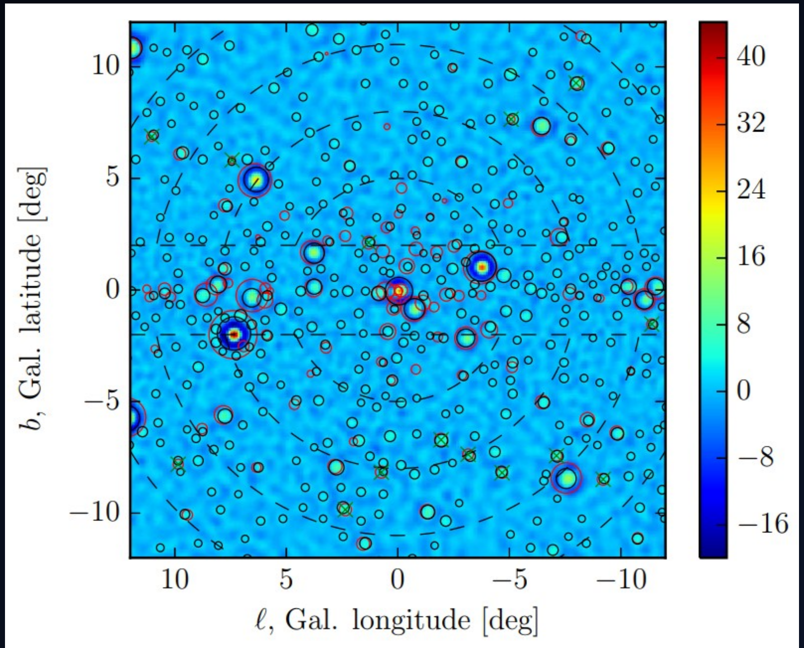
2.



Bartels, Krishnamurthy, Weniger (PRL '15)

2016-2018:
REIGN OF THE PULSARS

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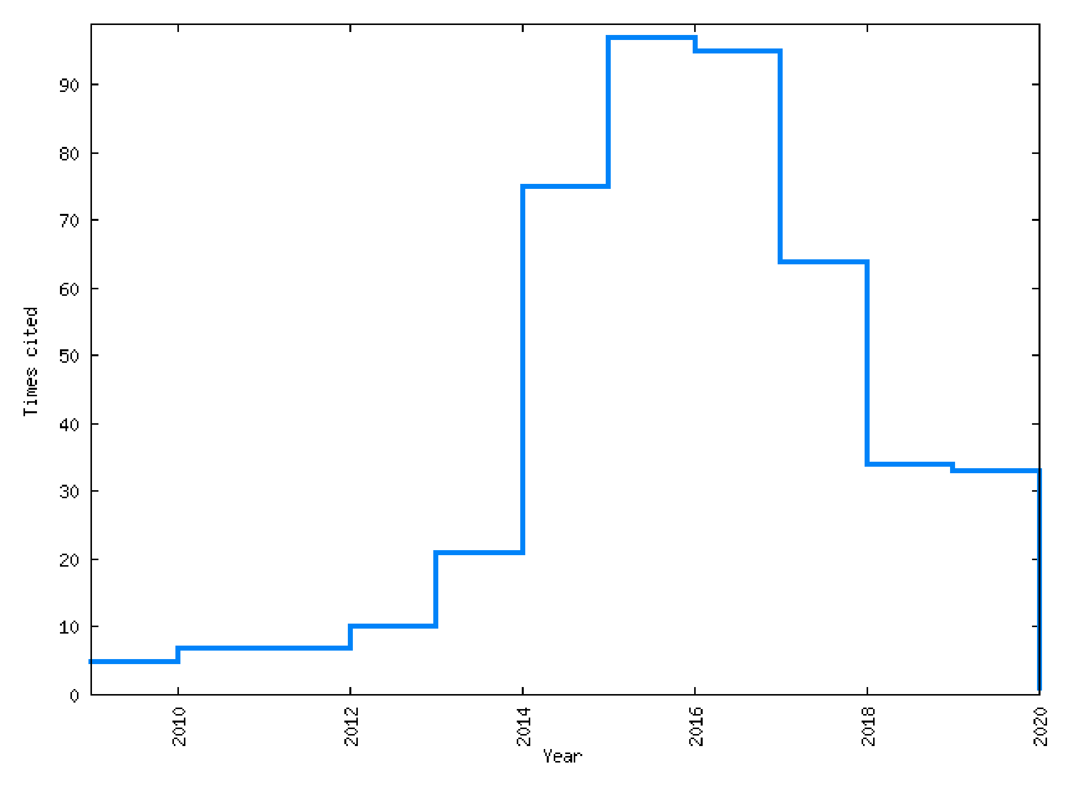
HOOPER+GOODENOUGH CITATIONS

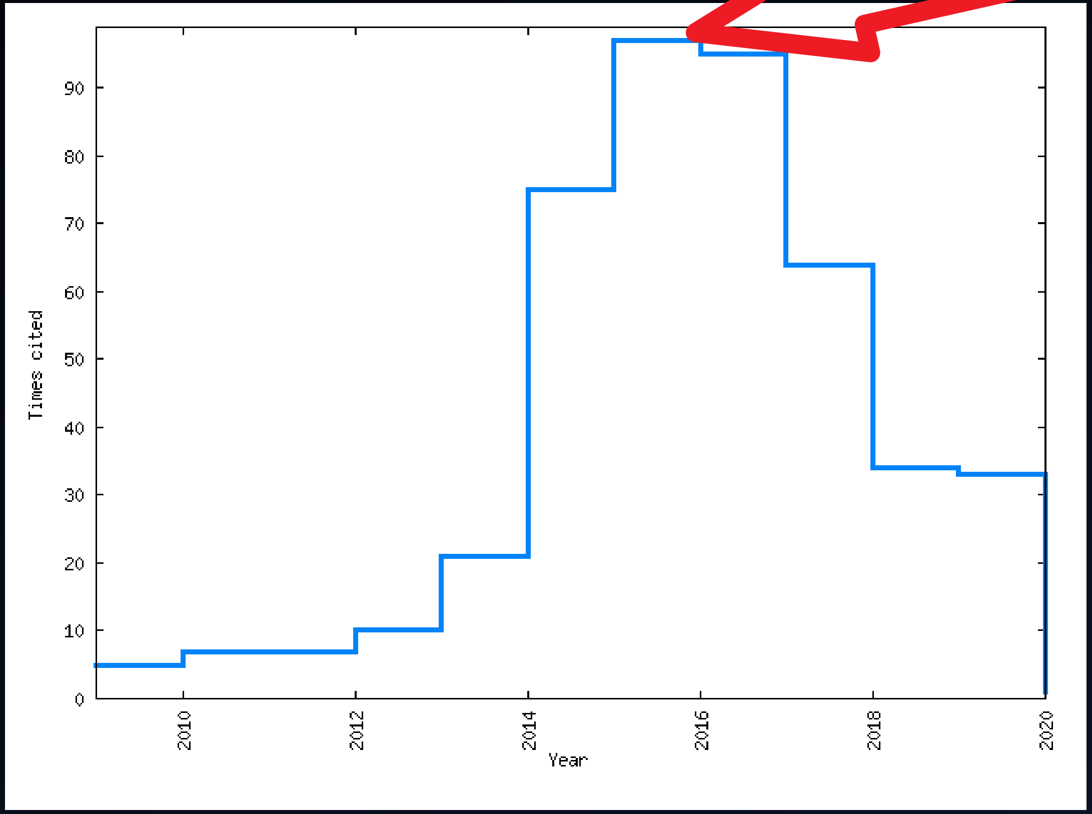


Inspire-HEP, citations per year

Rebecca Leane

HOOPER+GOODENOUGH CITATIONS

Pulsar papers come out



Inspire-HEP, citations per year

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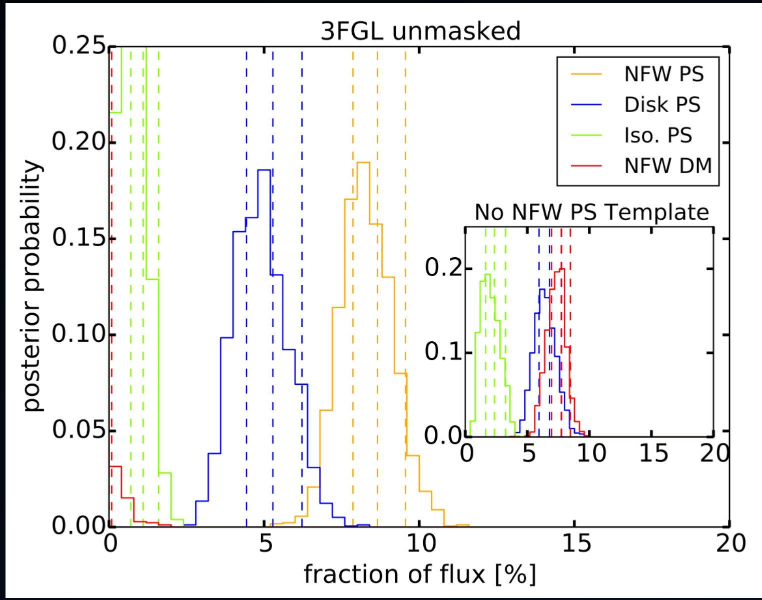

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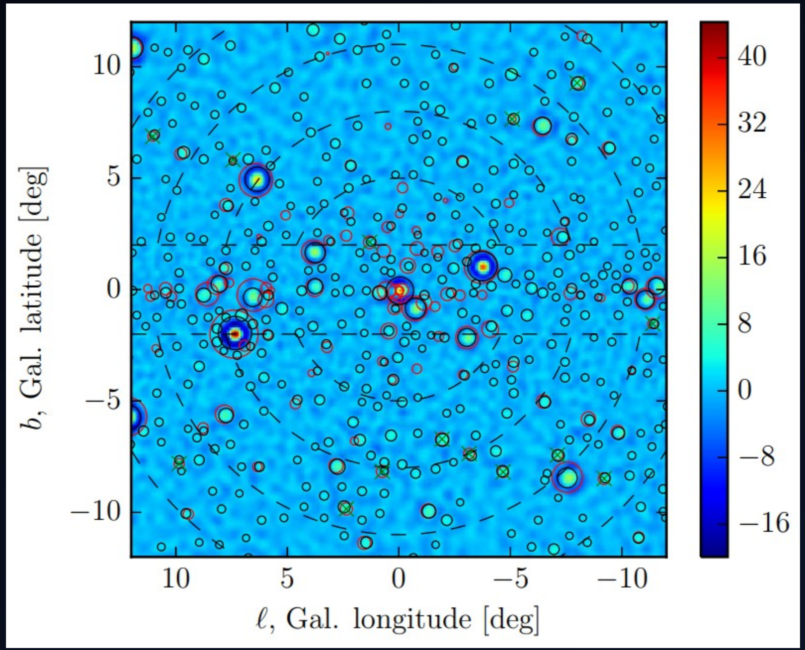

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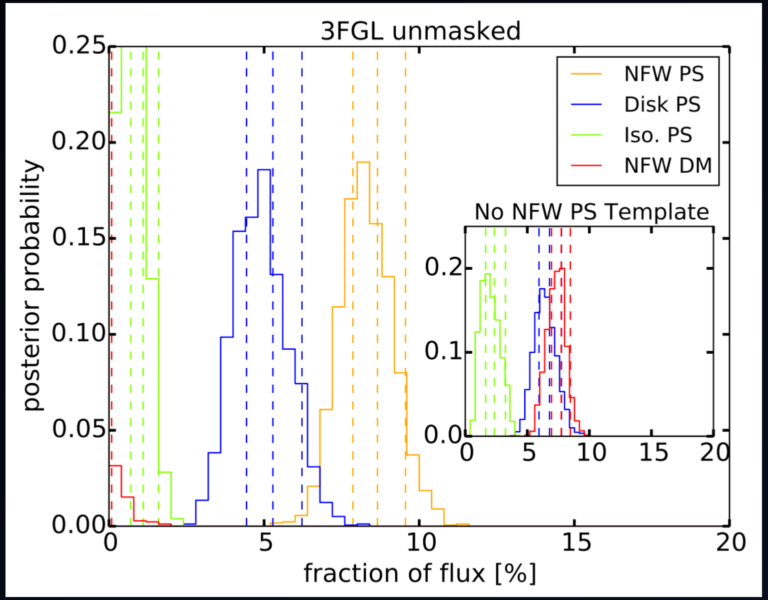
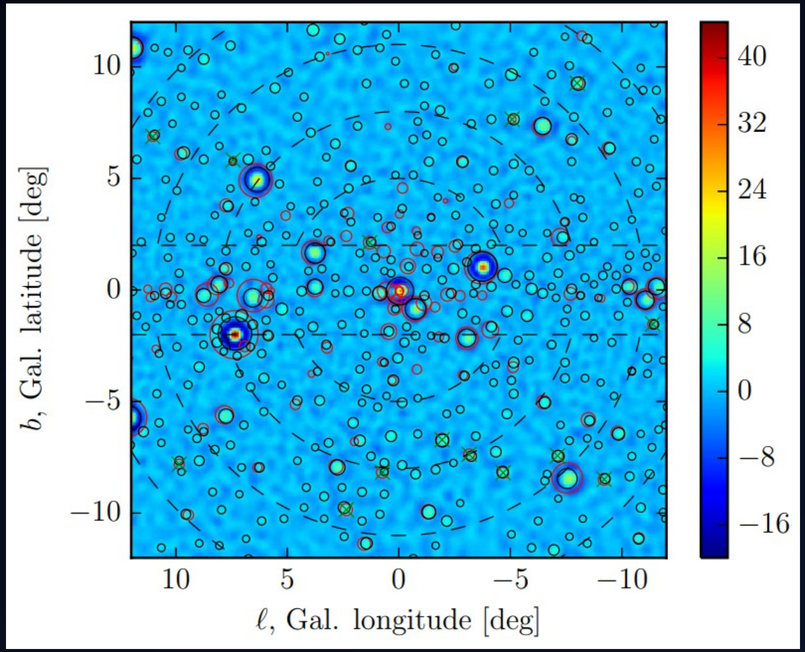


Lee, Lisanti, Safdi, Slatyer, Xue (PRL ‘15)



Bartels, Krishnamurthy, Weniger (PRL ’15)

2019

Rebecca Leane

WHAT IS DRIVING THIS PREFERENCE?

If there are some point sources present,
but **not** following one of these templates, could this:

+ **push up** the point source signal found with the current templates
and
- **push down** the inferred dark matter signal?

RL+Slatyer (PRL '19)

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but **not** following one of these templates, could this:

+ **push up** the point source signal found with the current templates
and
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Investigate if a bias is possible:

1. In a simulated proof-of-principle scenario
2. In the real Fermi data

RL+Slatyer (PRL '19)

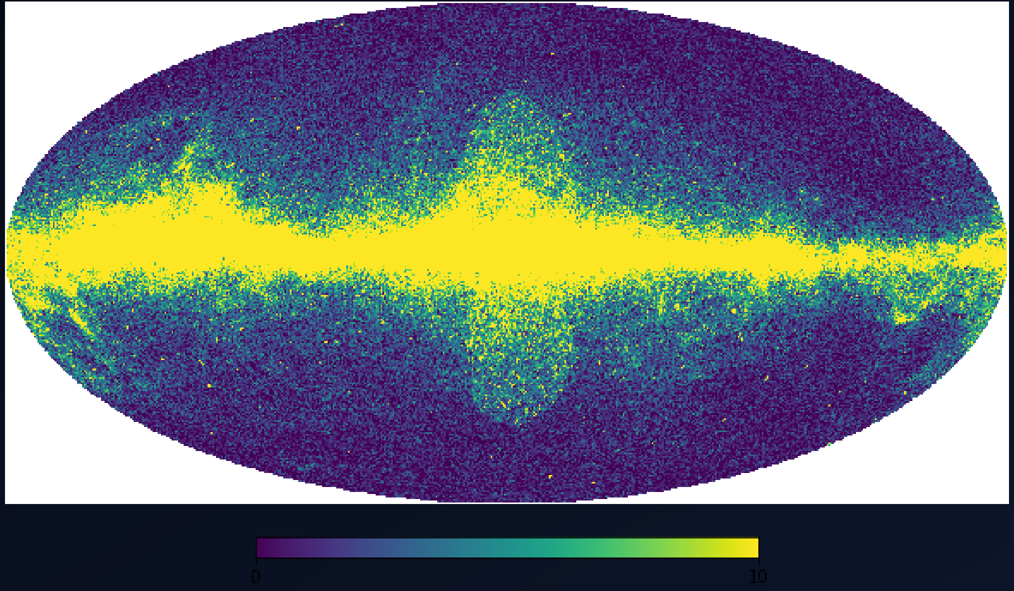
BIAS SEARCH USING SIMULATED DATA

Simulate:

- Point Sources: along the Galactic Disk and Bubbles

  Bubbles are the new ingredient, which we simulate as a possible source of bias

- Smooth emission: from isotropic+diffuse background, bubbles, and dark matter.



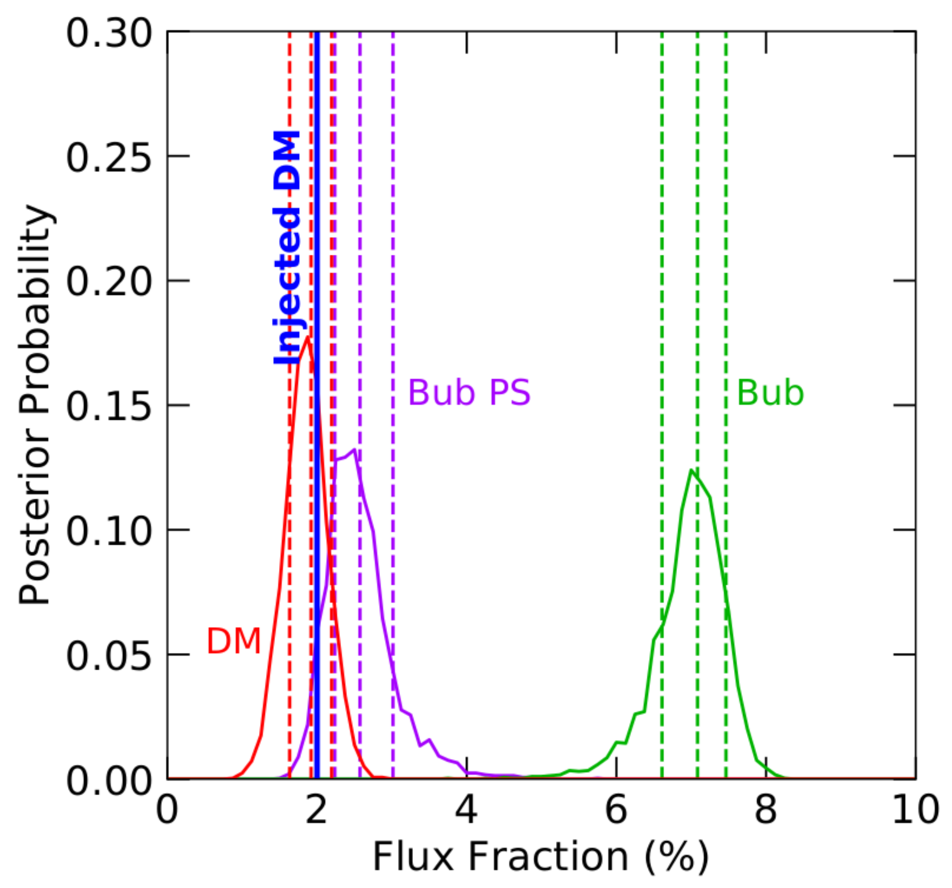
RL+Slatyer (PRL ‘19)

Analyze this data, with exactly the same templates.

RL+Slatyer (PRL '19)

Analyze this data, with exactly the same templates.

Return same normalizations.



RL+Slatyer (PRL '19)

What if we now instead analyze the data with NFW distributed PS instead of the PS bubbles?

RL+Slatyer (PRL '19)

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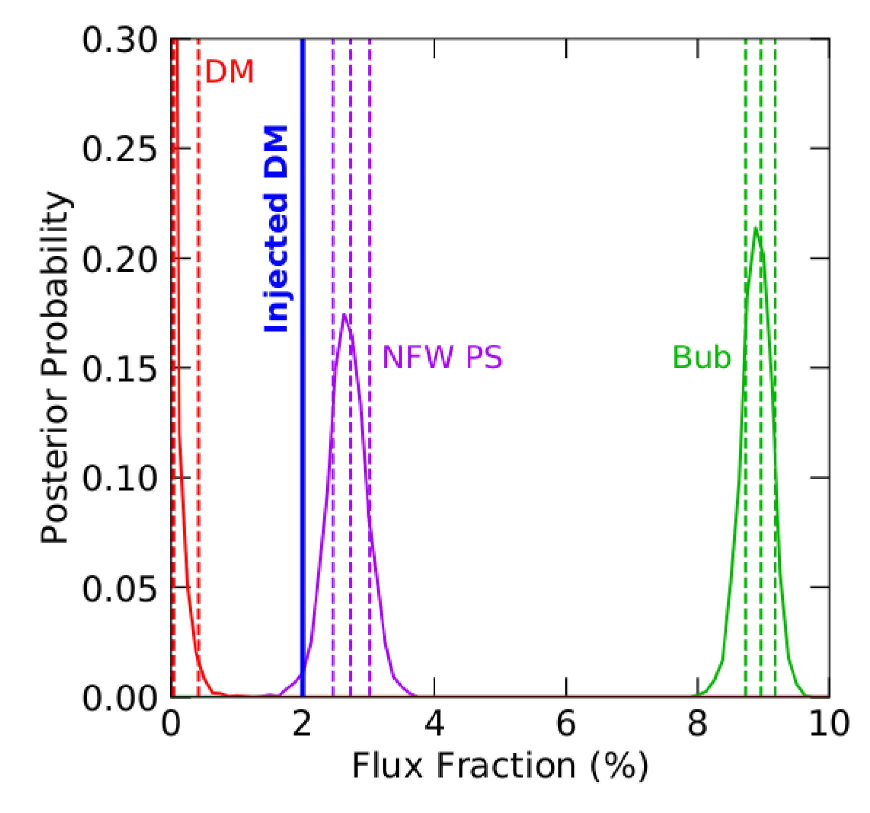
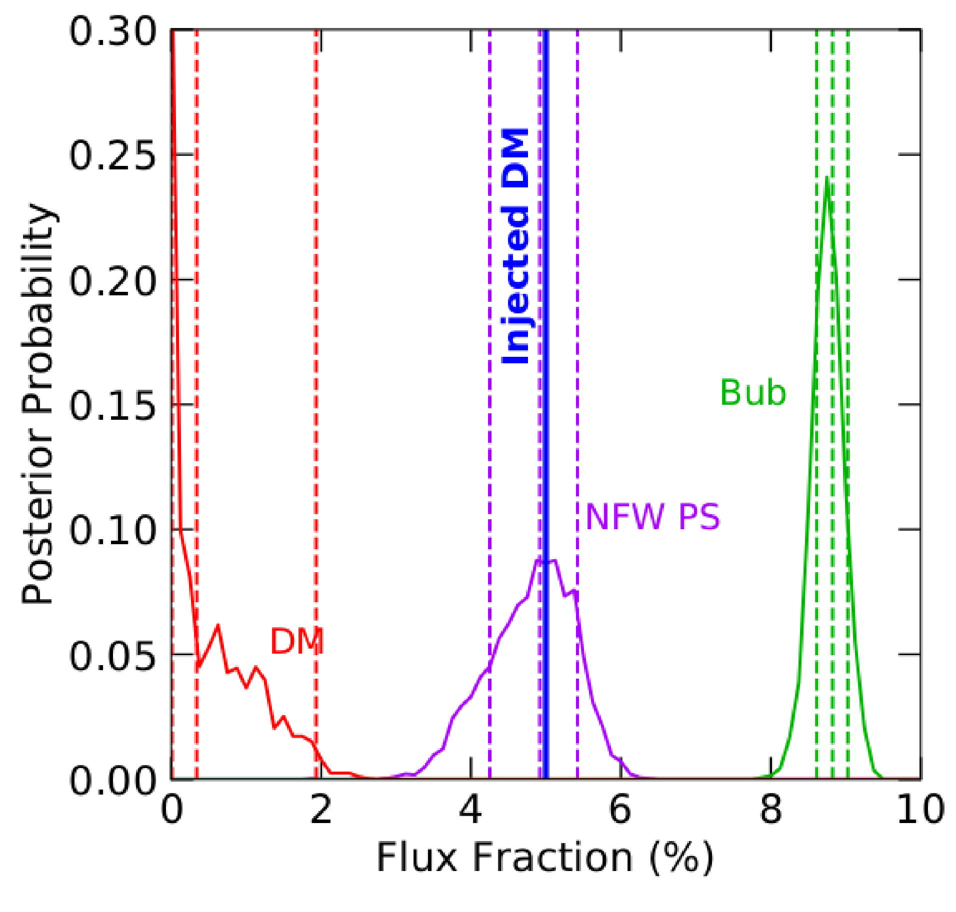


The dark matter signal is misattributed to point sources!

RL+Slatyer (PRL '19)

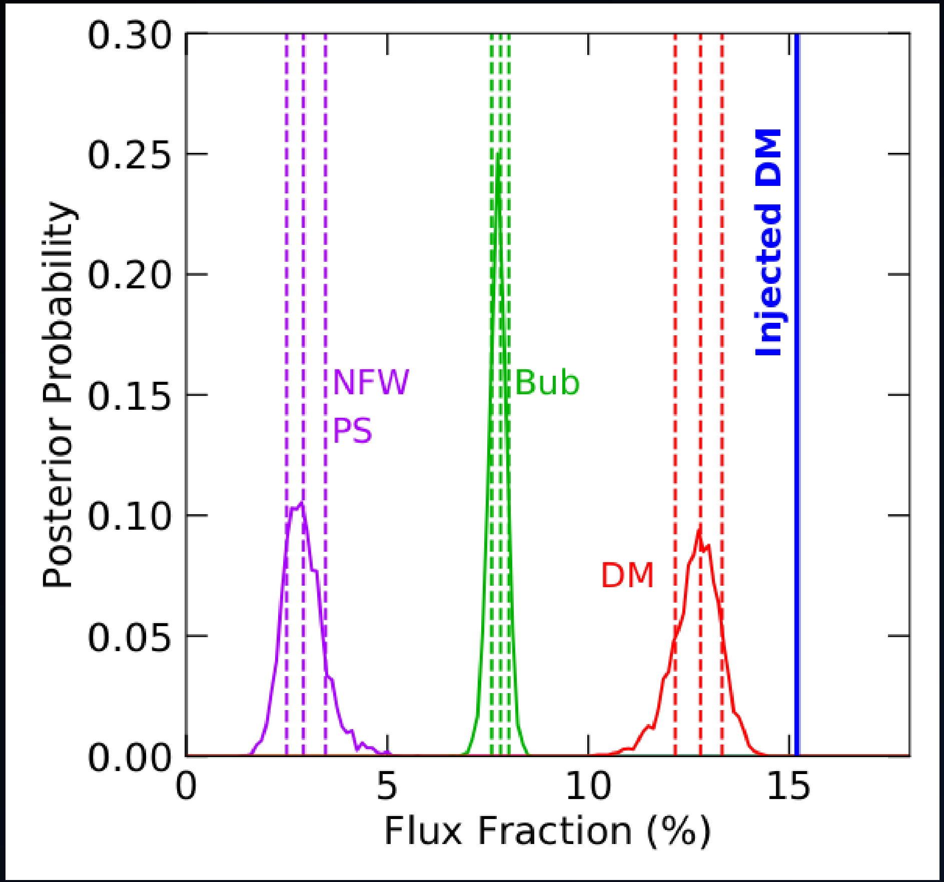
Add even more....



The dark matter signal is misattributed to point sources!

RL+Slatyer (PRL ‘19)

IS THERE A THRESHOLD IN SIMULATIONS?



Inject an order of magnitude more DM (~15%)

Takes this much to reconstruct DM, but still not all of it

RL+Slatyer (PRL '19)

EVIDENCE OF MISATTRIBUTED DM

- Cross talk between templates appears to be possible, when an unmodelled component is present
- Large Bayes factor preference for adding NFW PS, and pushing DM flux down, just like Lee at al ‘15 paper

…and in this case we KNOW dark matter is there!

RL+Slatyer (PRL ‘19)

ARE THERE BUBBLES POINT SOURCES?

- No evidence
- Serves as proof-of-principle example of mismodeling impact

RL+Slatyer (PRL '19)

TESTING WITH THE REAL FERMI DATA

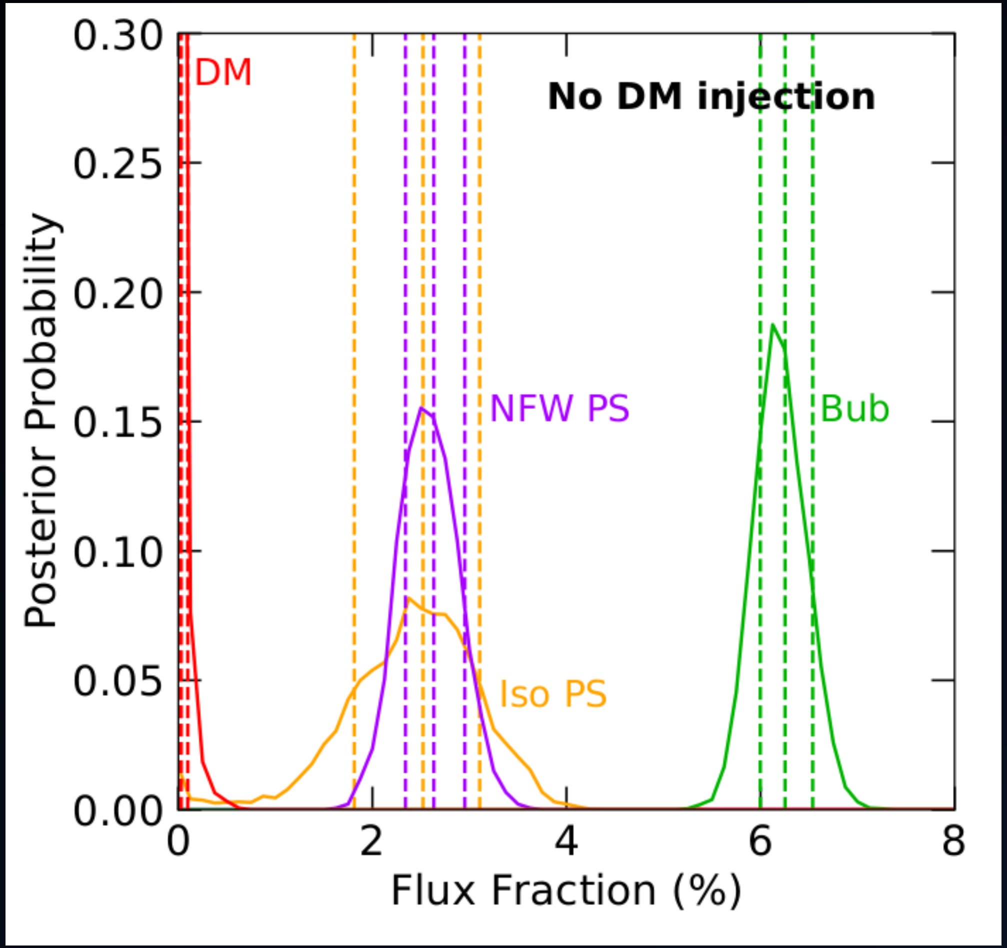
If this effect is present, template likely not saturated in its ability to absorb dark matter flux.

Inject a fake dark matter signal into the Fermi data.

RL+Slatyer (PRL '19)

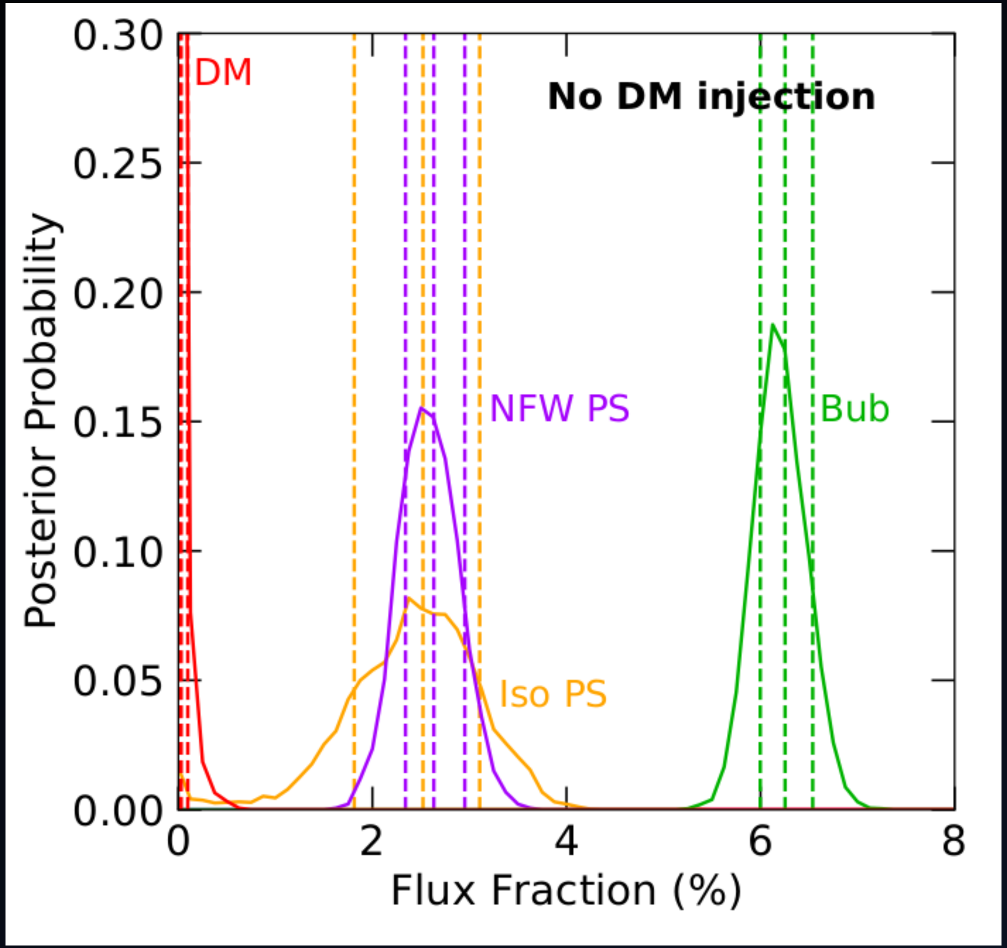
FERMI DATA

INJECTED DM SIGNAL + DATA

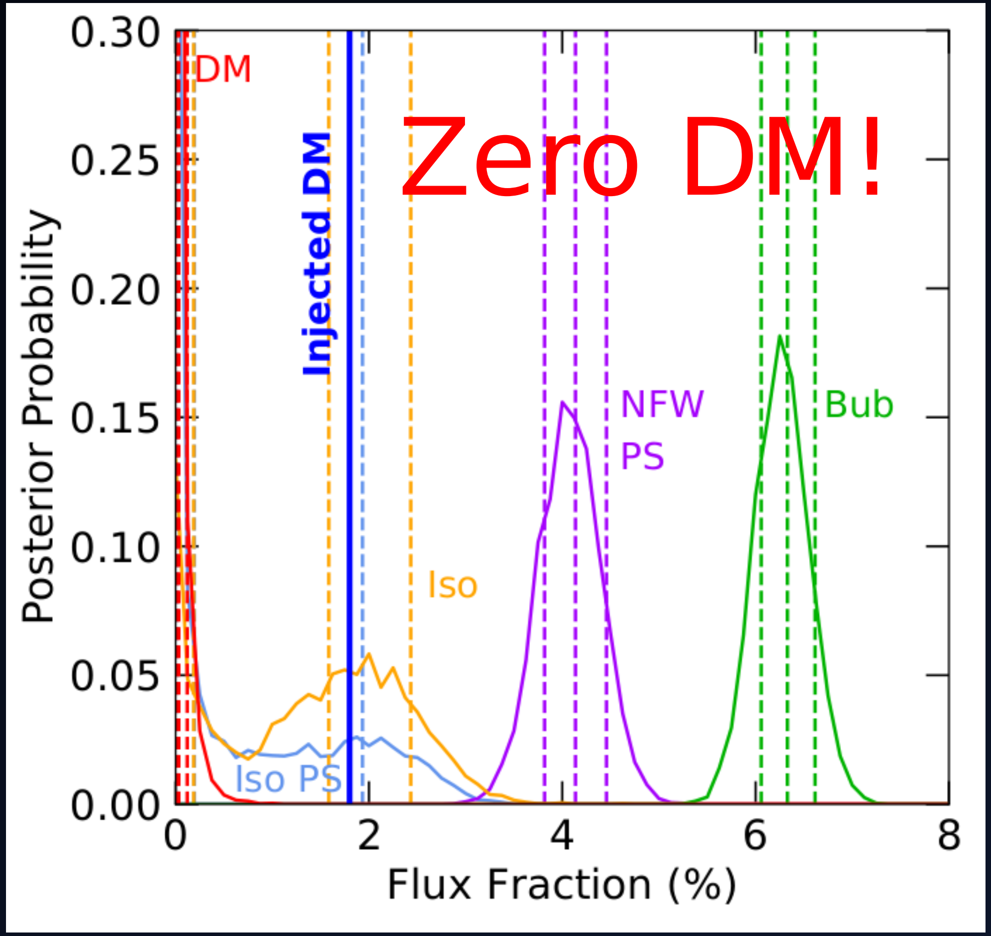


RL+Slatyer (PRL '19)

FERMI DATA



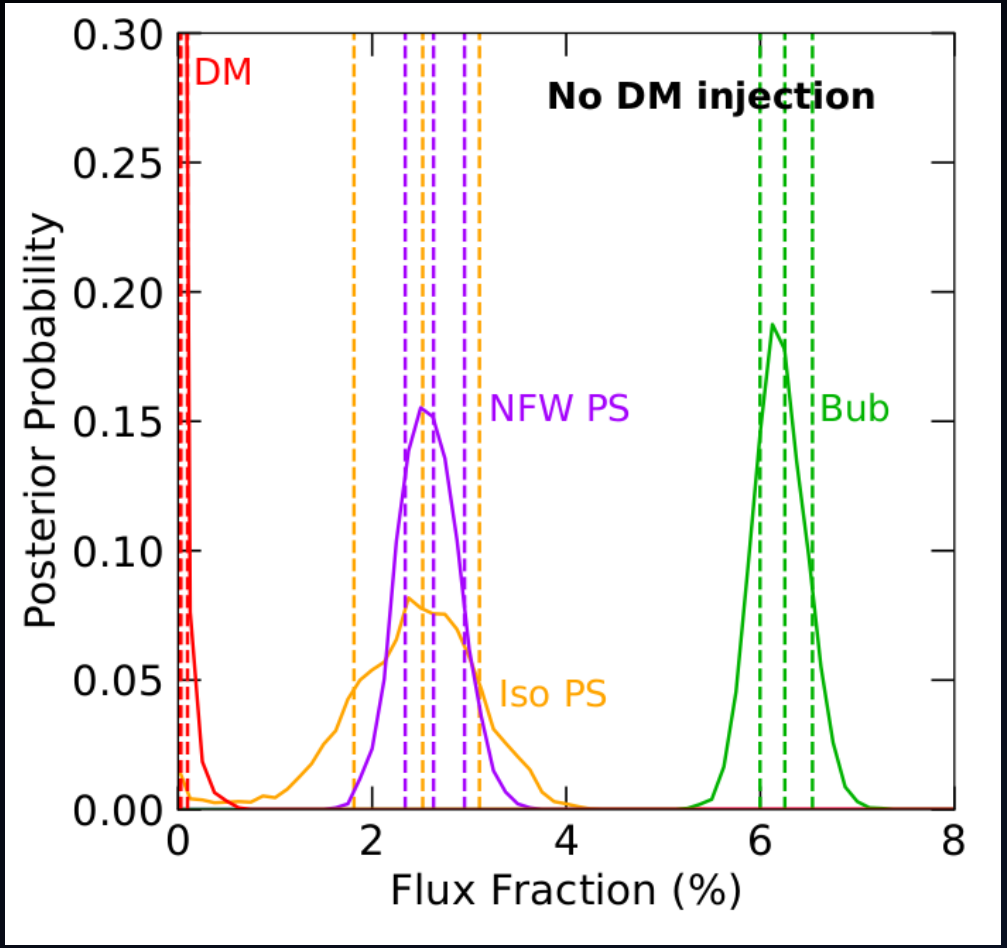
INJECTED DM SIGNAL + DATA



RL+Slatyer (PRL ‘19)

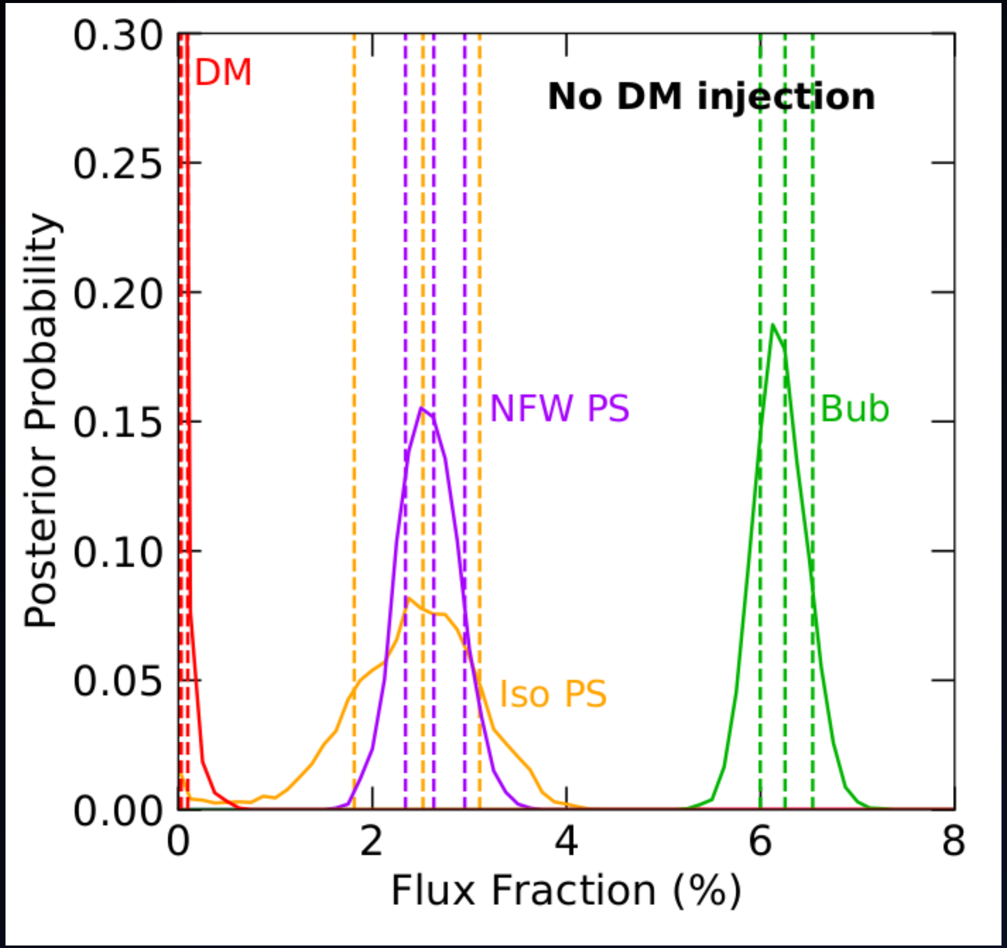
FERMI DATA

LARGER INJECTED DM SIGNAL + DATA

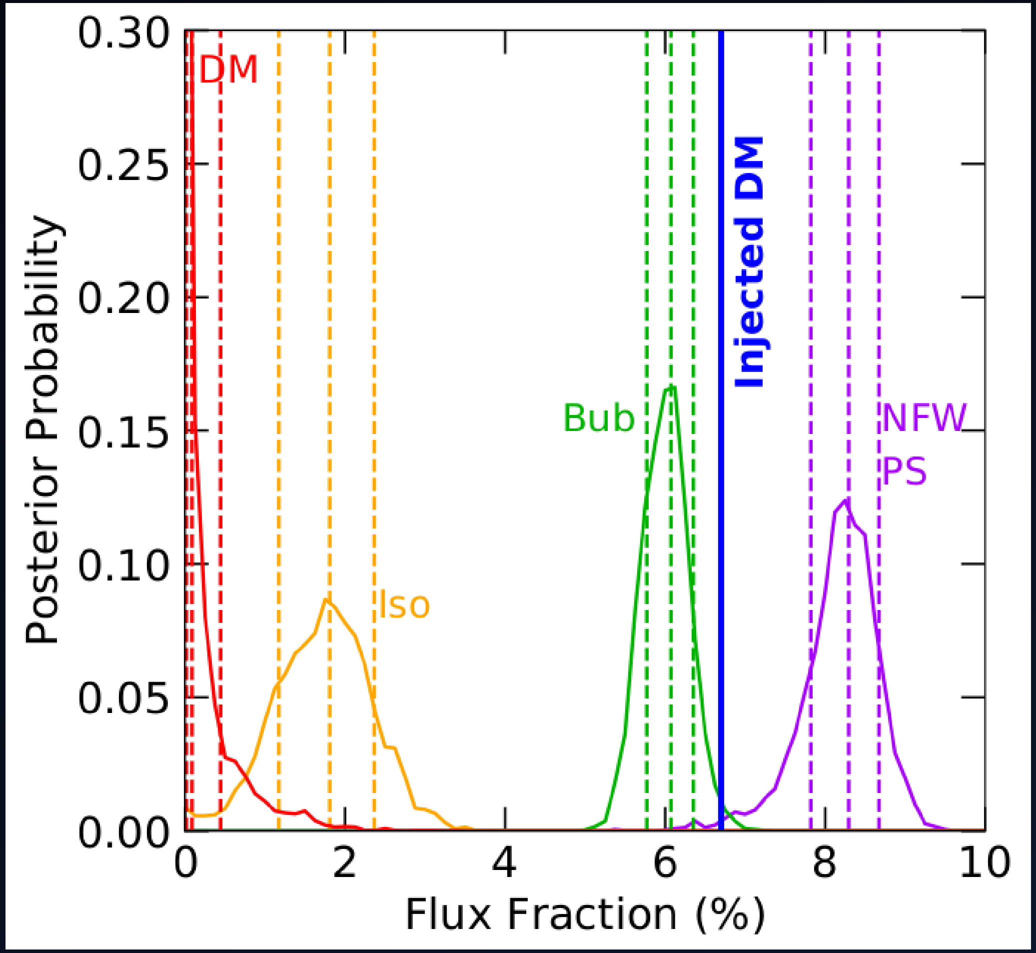


RL+Slatyer (PRL '19)

FERMI DATA



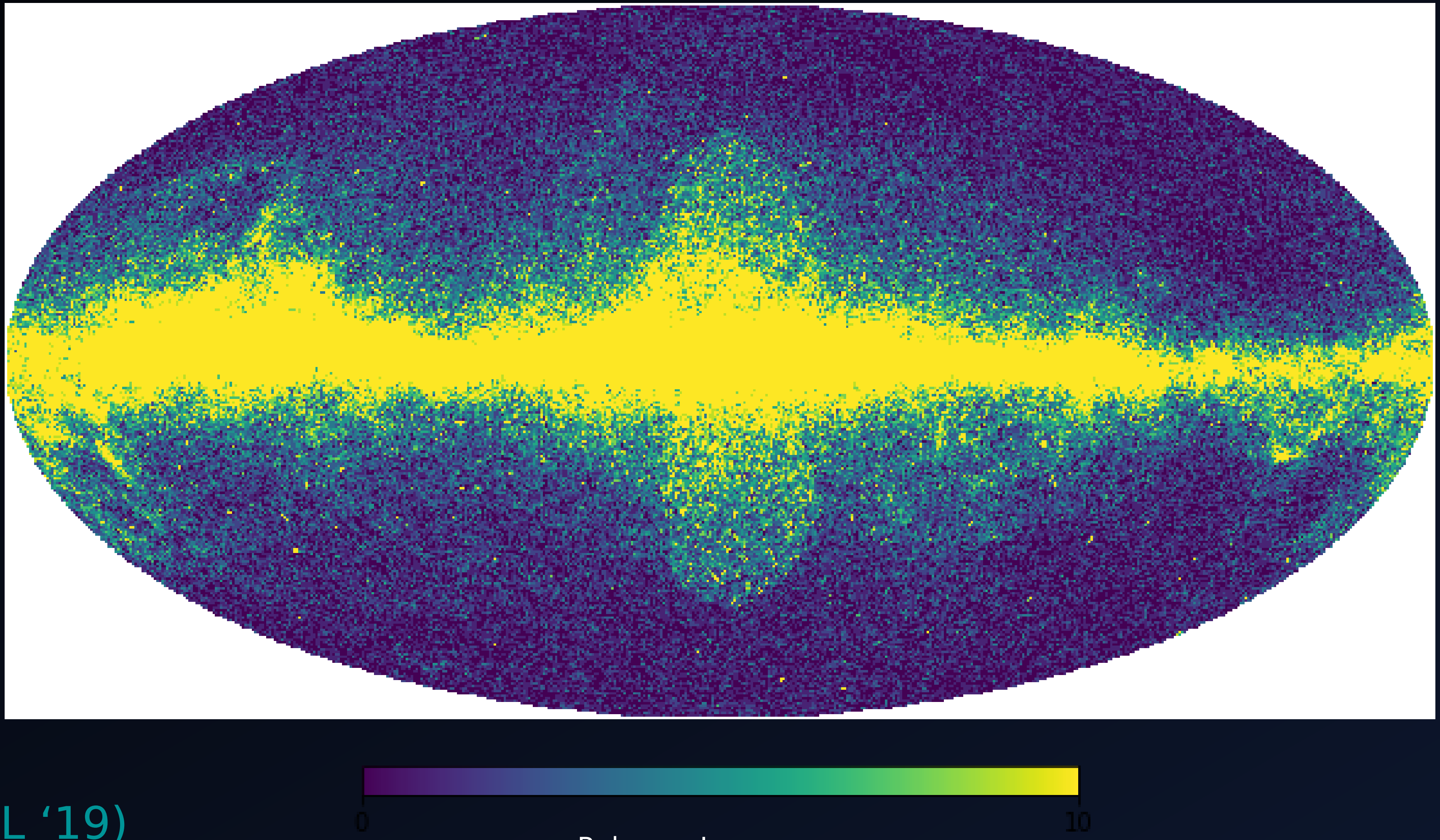
LARGER INJECTED DM SIGNAL + DATA



Zero DM!

RL+Slatyer (PRL ‘19)

BOMBARD THE GALAXY!



RL+Slatyer (PRL '19)

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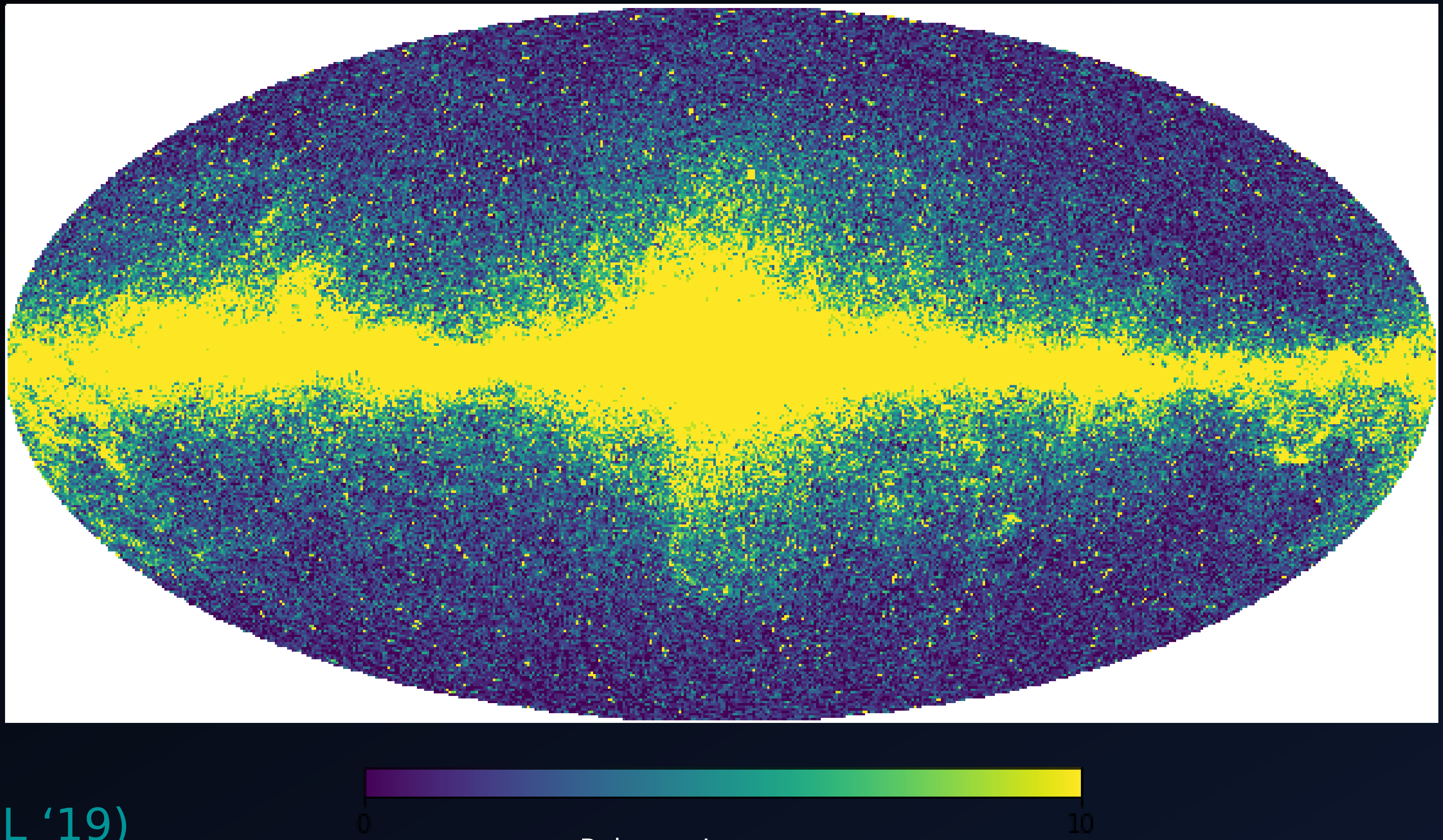
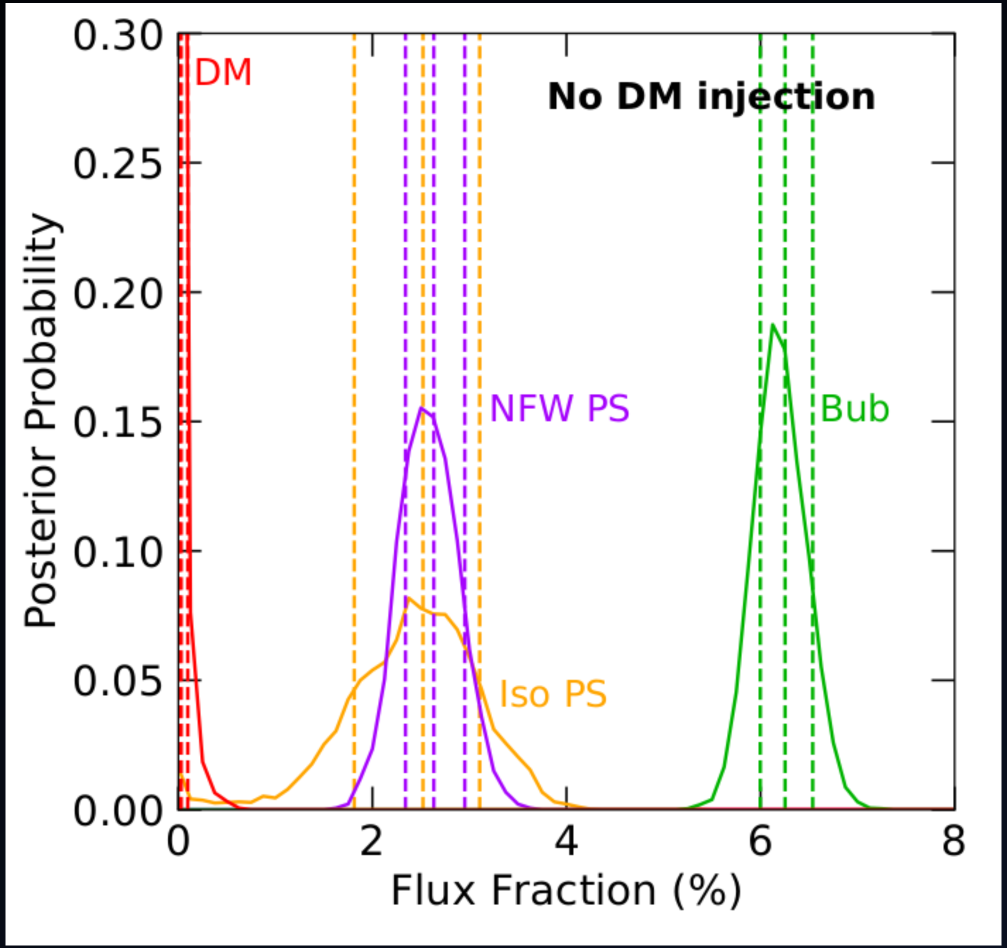


RL+Slatyer (PRL ‘19)

FERMI DATA

BOMBARDED DM SIGNAL + DATA



RL+Slatyer (PRL '19)

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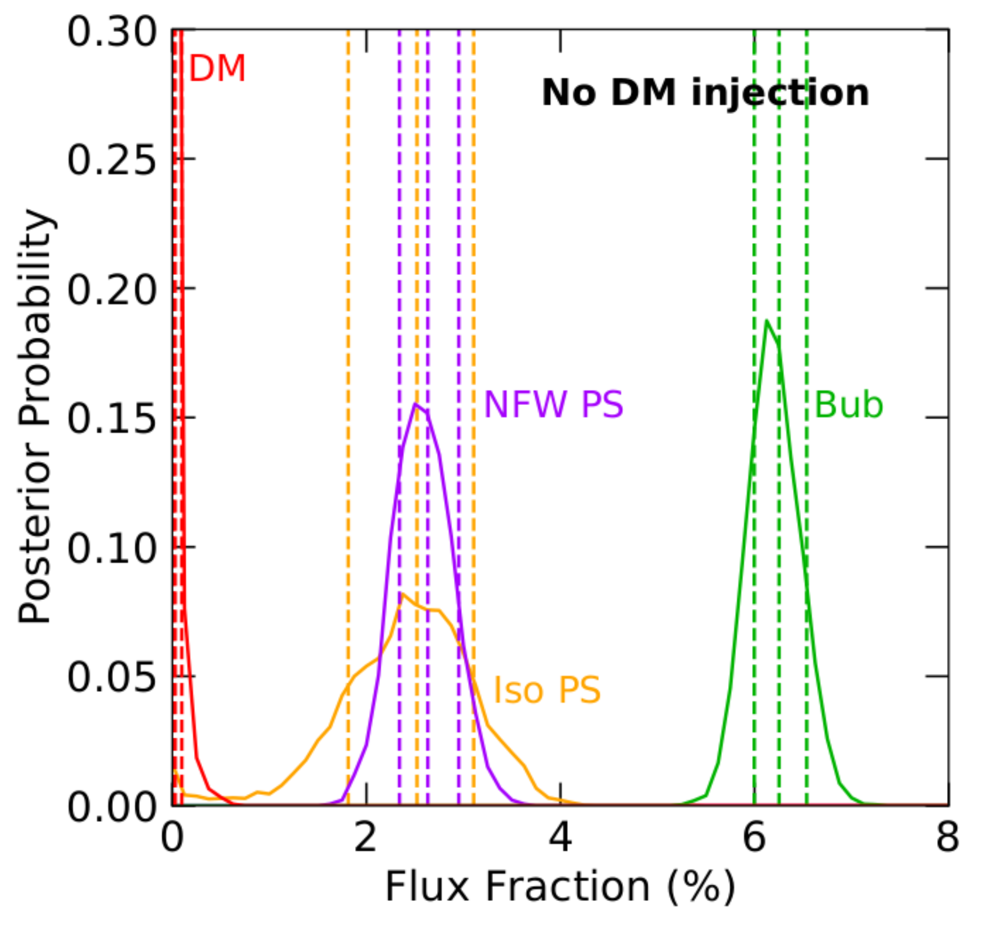
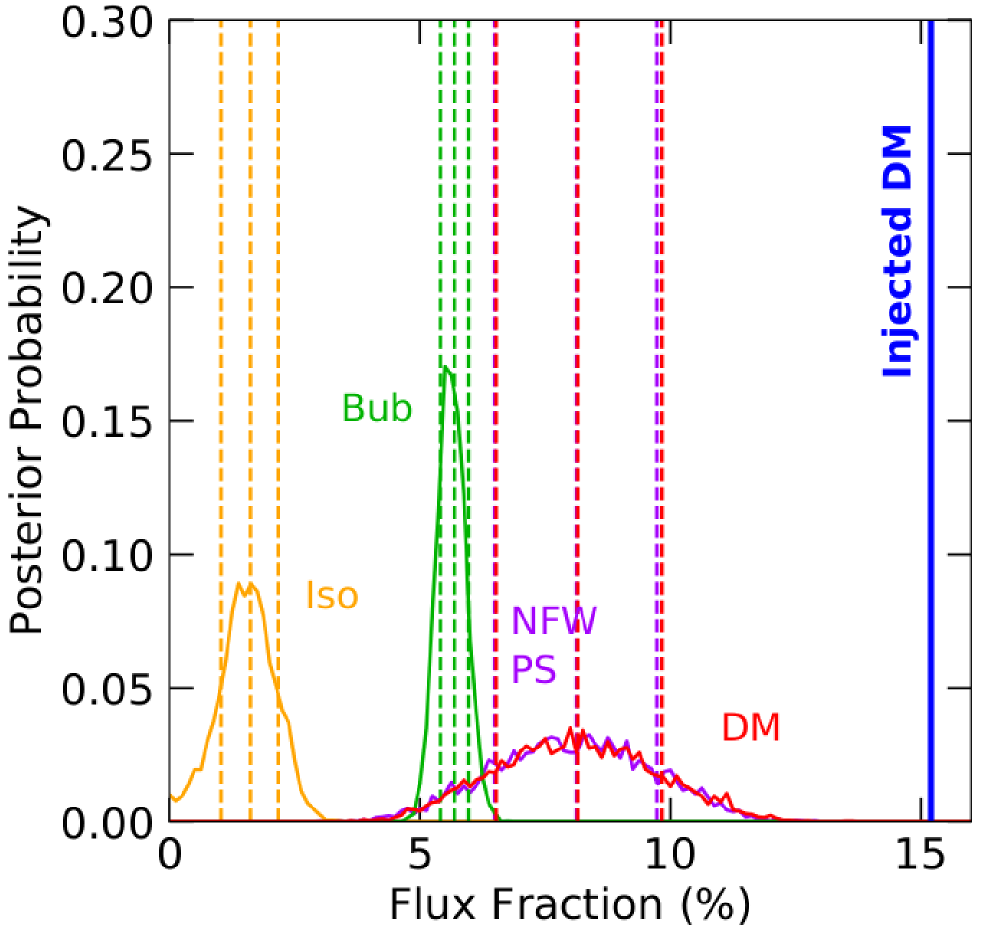


BOMBARDED DM SIGNAL + DATA



Finally, but low.

RL+Slatyer (PRL '19)

- Both simulated example and real data show similar behavior: significant preference against DM interpretation of the data

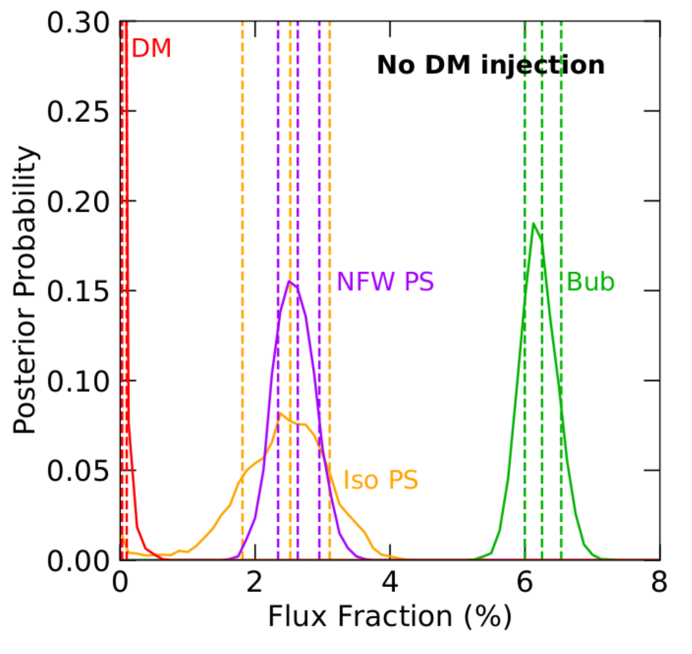
- A potential DM signal could be incorrectly discarded: due to the presence of a not yet discovered unresolved PS population, or another mismodelling effect

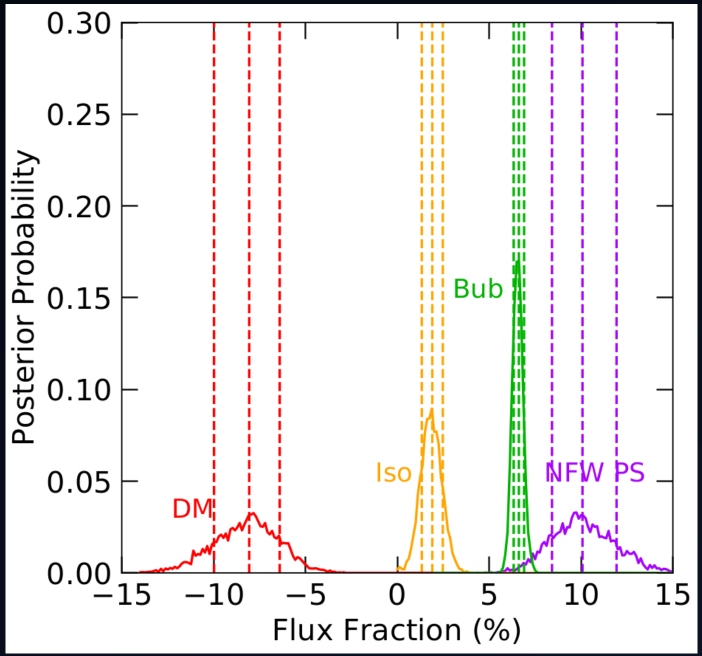
- *DM could substantially contribute to the GCE!*

RL+Slatyer (PRL '19)

ALTERNATIVE TO INJECTION: GOING NEGATIVE

Prior of DM normalization only allowed to float positive





Prior of DM normalization also allowed to float negative

Shows the degeneracy of smooth signals (DM vs faint point sources) does not explain this behavior

Observed that degree of oversubtraction varied with diffuse models; effect likely due to diffuse mismodeling

RL+Slatyer, PRL '19

2019:
DARK MATTER STRIKES BACK

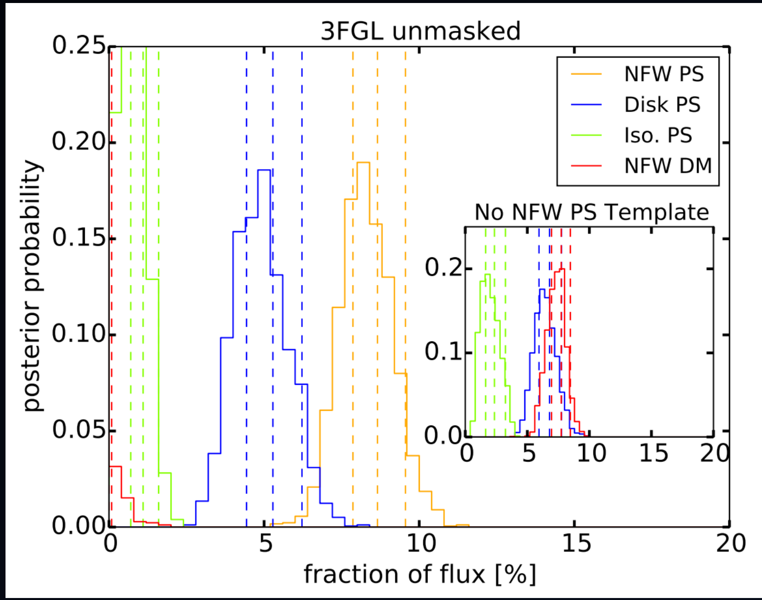
Dark Matter Strikes Back at the Galactic Center

Rebecca K. Leane[1,*] and Tracy R. Slatyer[1,2,†]

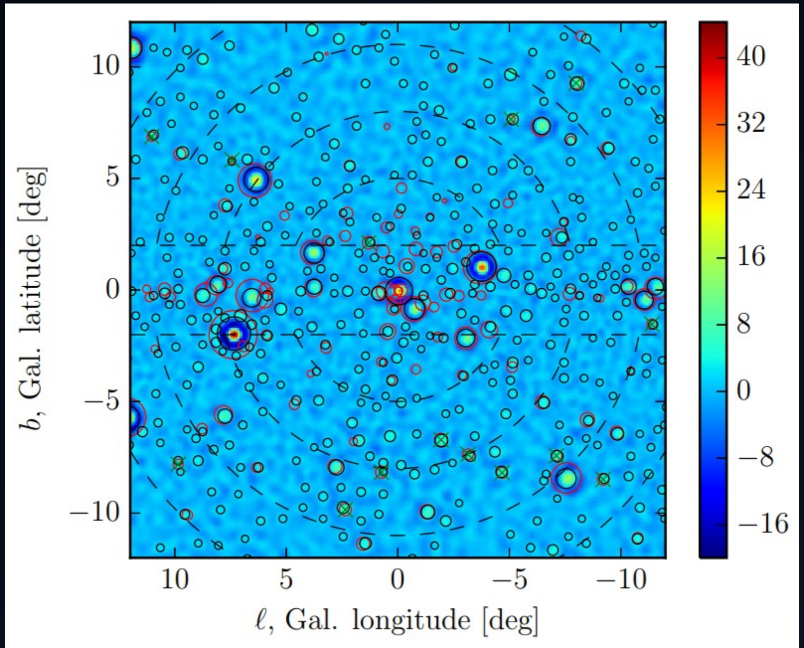
[1] *Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[2] *School of Natural Sciences, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540, USA*

(Dated: April 19, 2019)

EVIDENCE FOR POINT SOURCES AT THE GALACTIC CENTER



Lee, Lisanti, Safdi, Slatyer, Xue (PRL ‘15)



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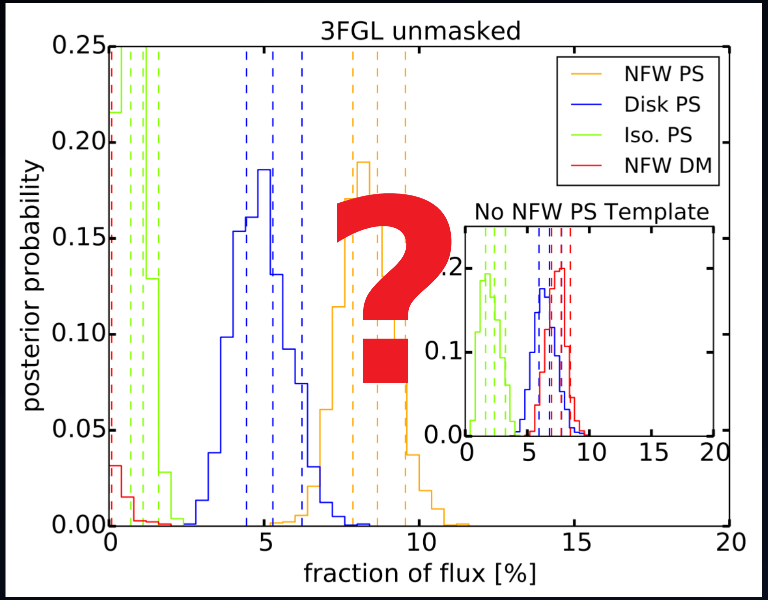

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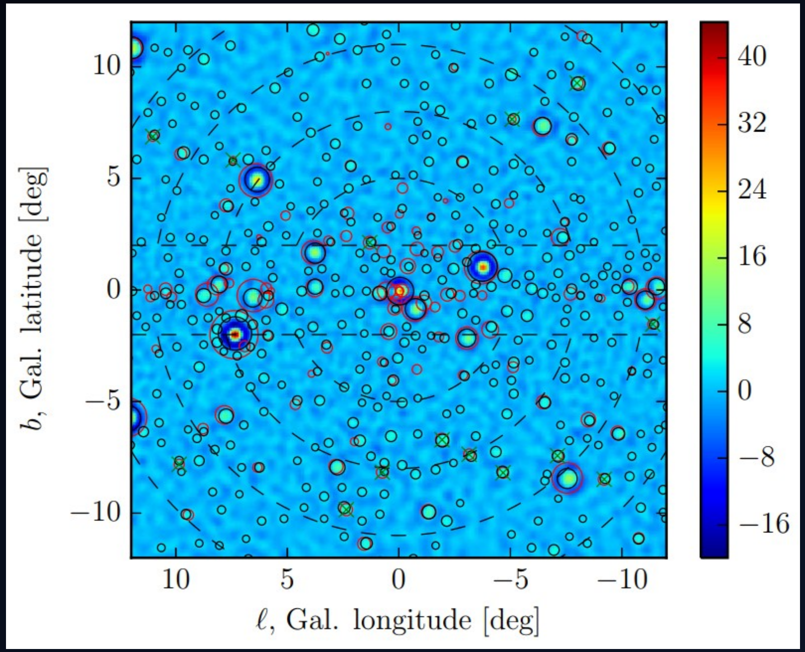

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Challenged
RL+Slatyer (PRL '19)

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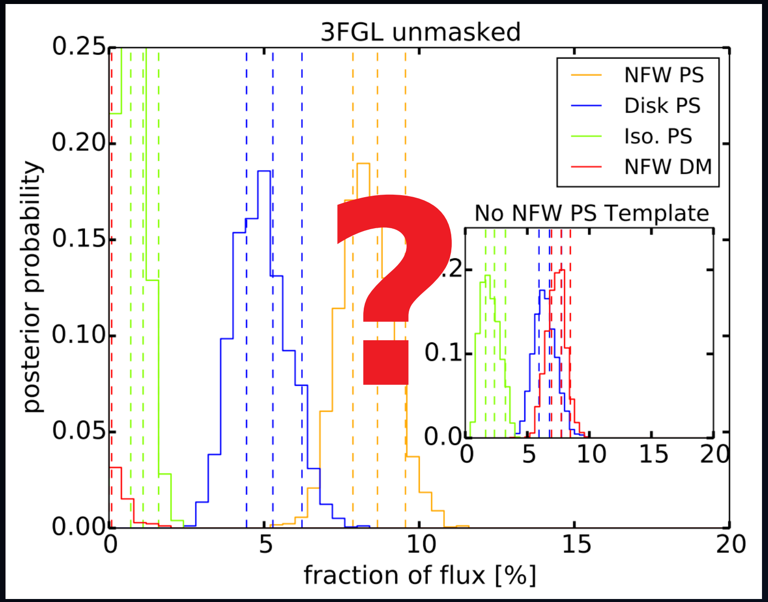

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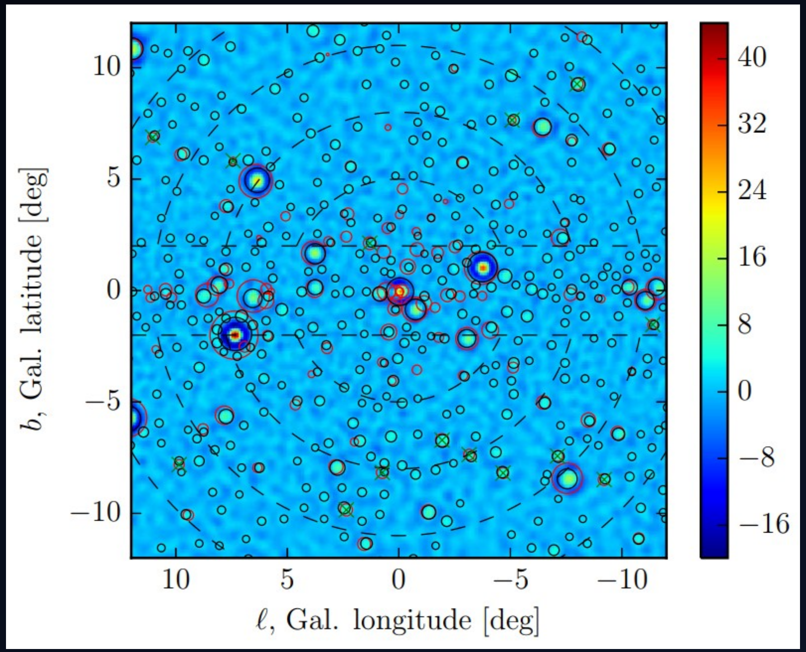

Bartels, Krishnamurthy, Weniger (PRL '15)

WAVELET METHOD RE-EVALUATION

Updated to mask out Fermi’s new point source catalog.

Rebecca Leane

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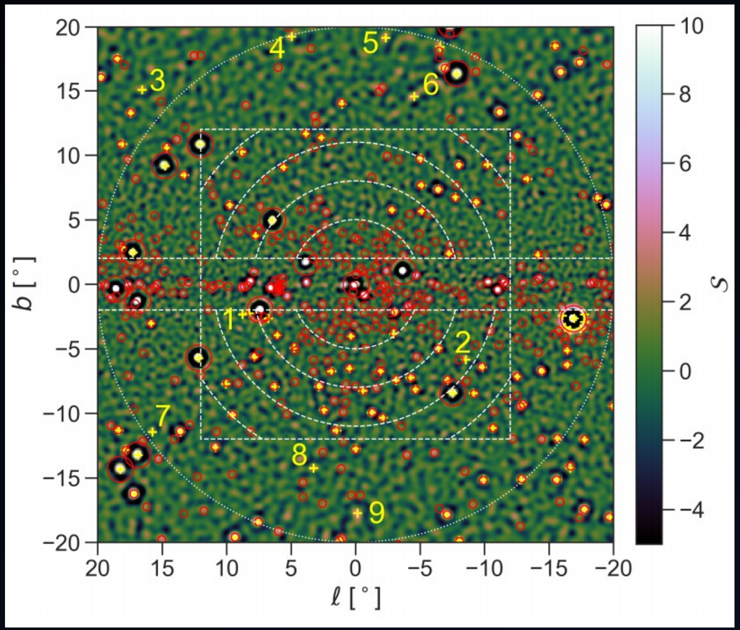
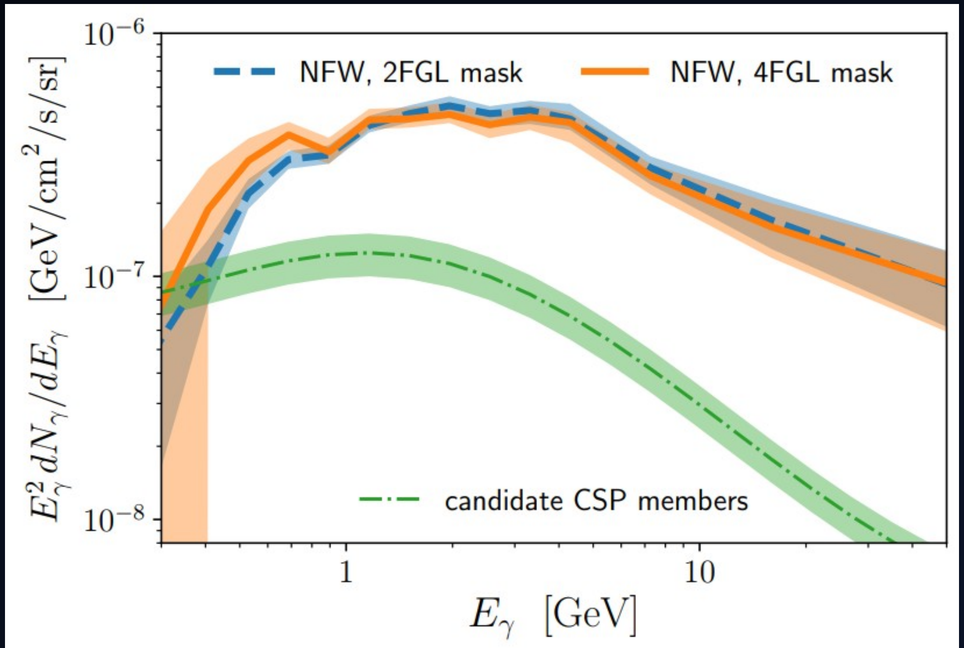


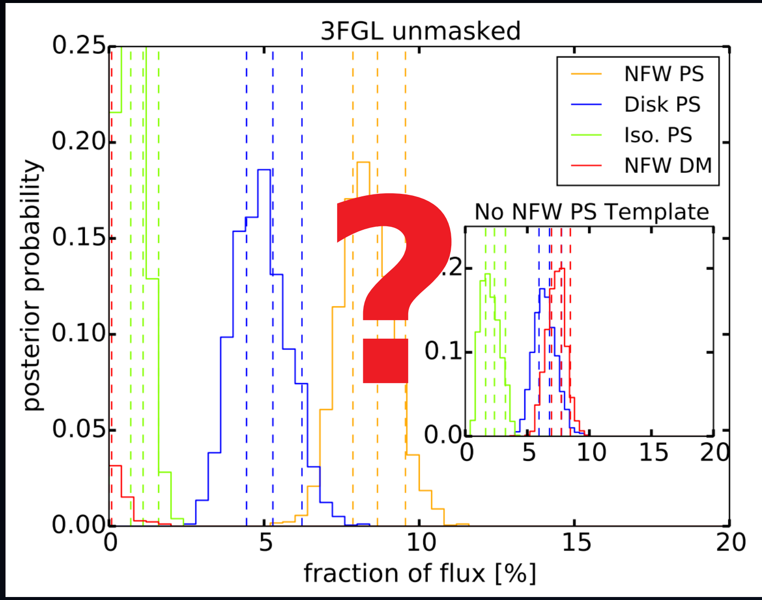


Turns out the 2015 paper correctly found point sources

...but **not** point sources that can explain the excess.

Zhong, McDermott, Cholis, Fox PRL '19

EVIDENCE FOR POINT SOURCES AT THE GALACTIC CENTER



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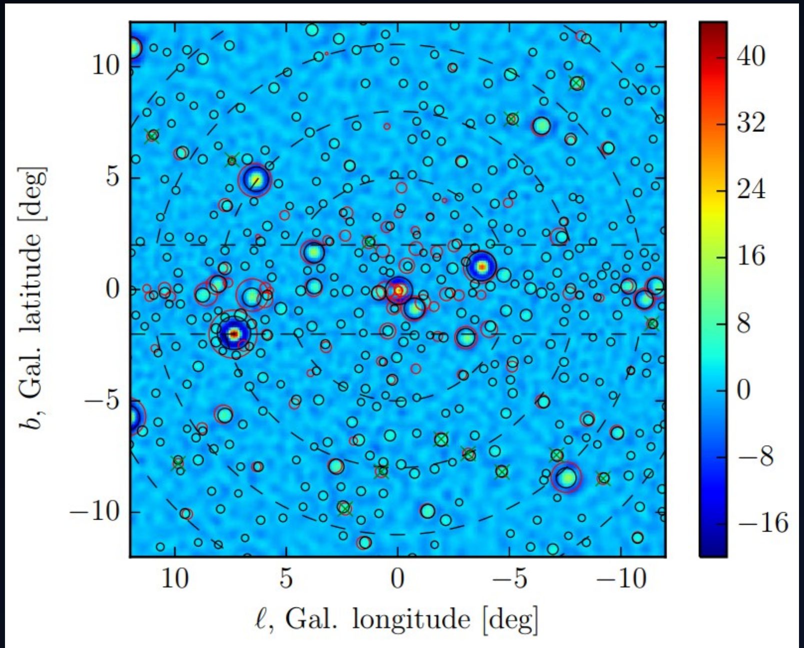

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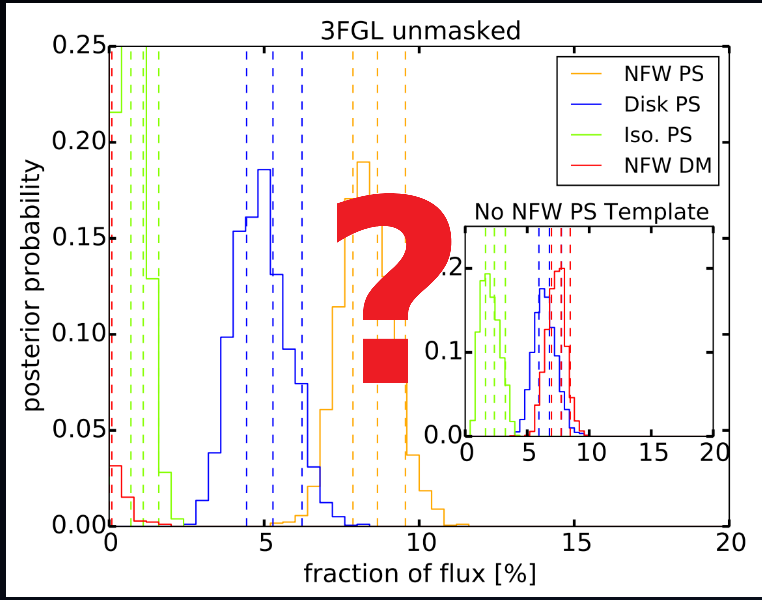

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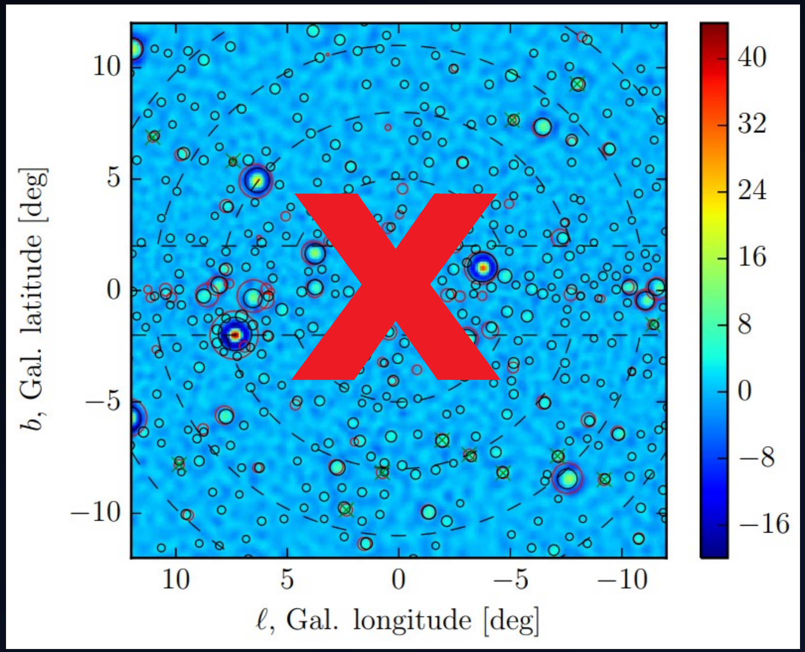

Bartels, Krishnamurthy, Weniger (PRL '15)

Shown these point sources are not bulk of excess

Zhong, McDermott, Cholis, Fox (PRL'19)

2020

Rebecca Leane

EFFECTS OF ADDITIONAL FREEDOM

- Break excess template into north and south pieces, let them float independently

RL+Slatyer (PRL ‘20)
RL+Slatyer (PRD ‘20)

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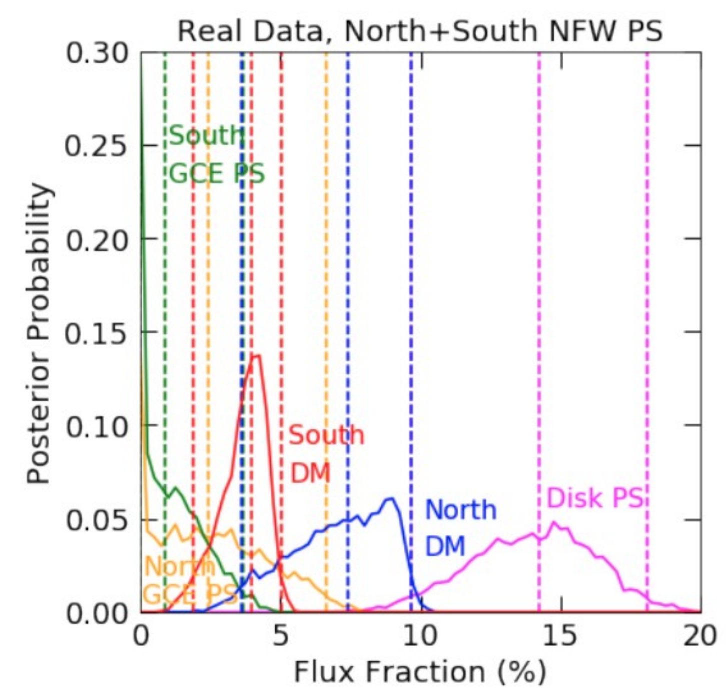


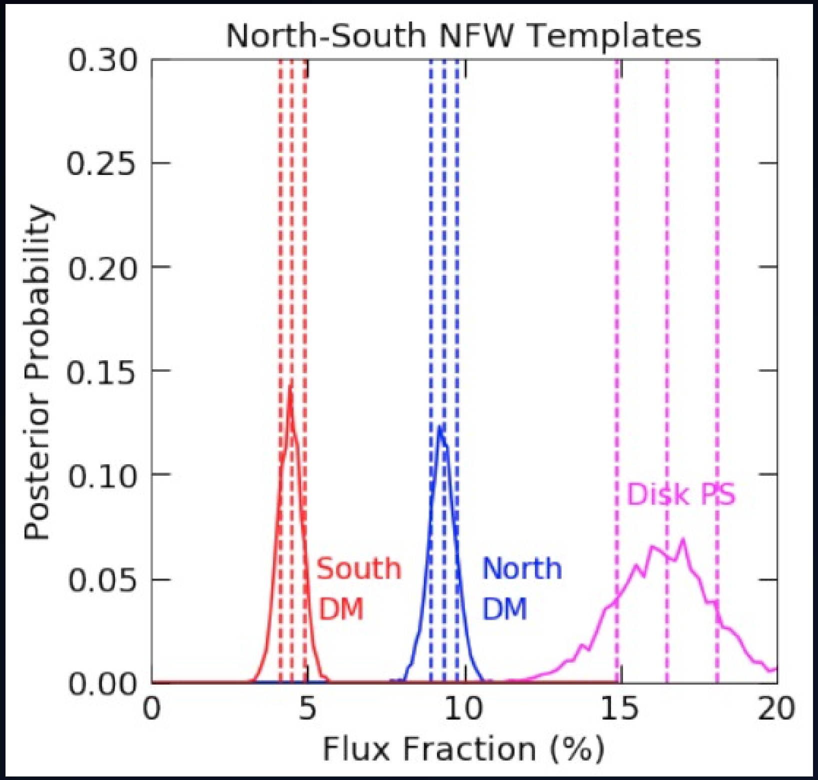
Preference for point sources:

Gone

RL+Slatyer (PRL '20)
RL+Slatyer (PRD '20)

THE DATA PREFERS THE FREEDOM

- Looking at only the smooth components

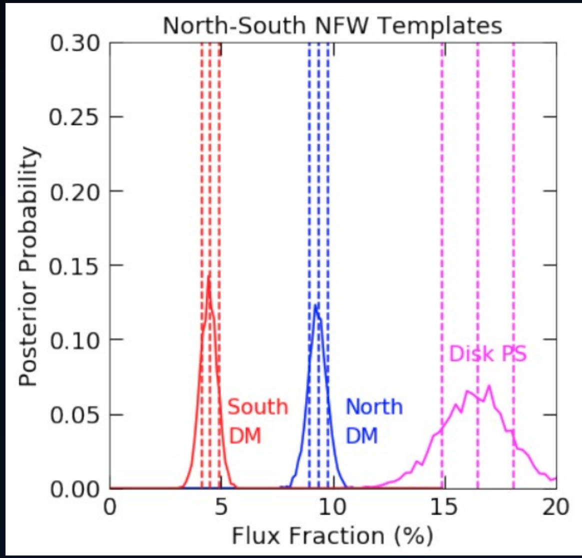


Data strongly prefer additional freedom, north/south asymmetry

RL+Slatyer (PRL ‘20)
RL+Slatyer (PRD ‘20)

REPRODUCE IN SIMULATIONS?

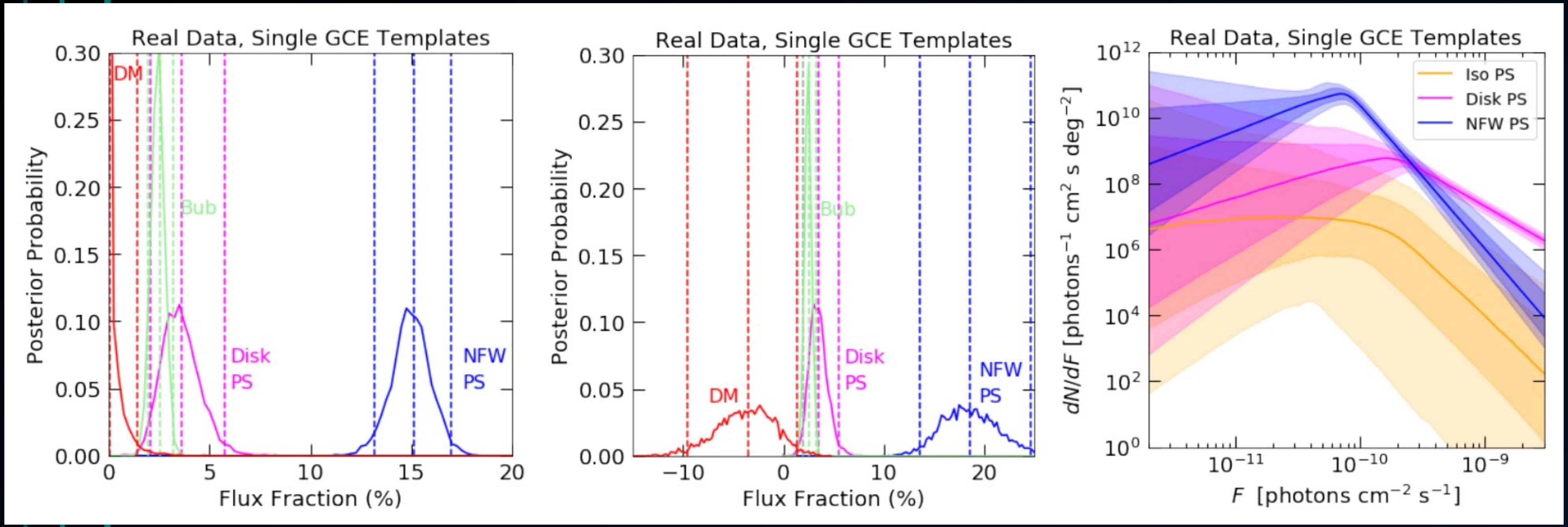
- Simulate the smooth asymmetry (best-fit to the data)



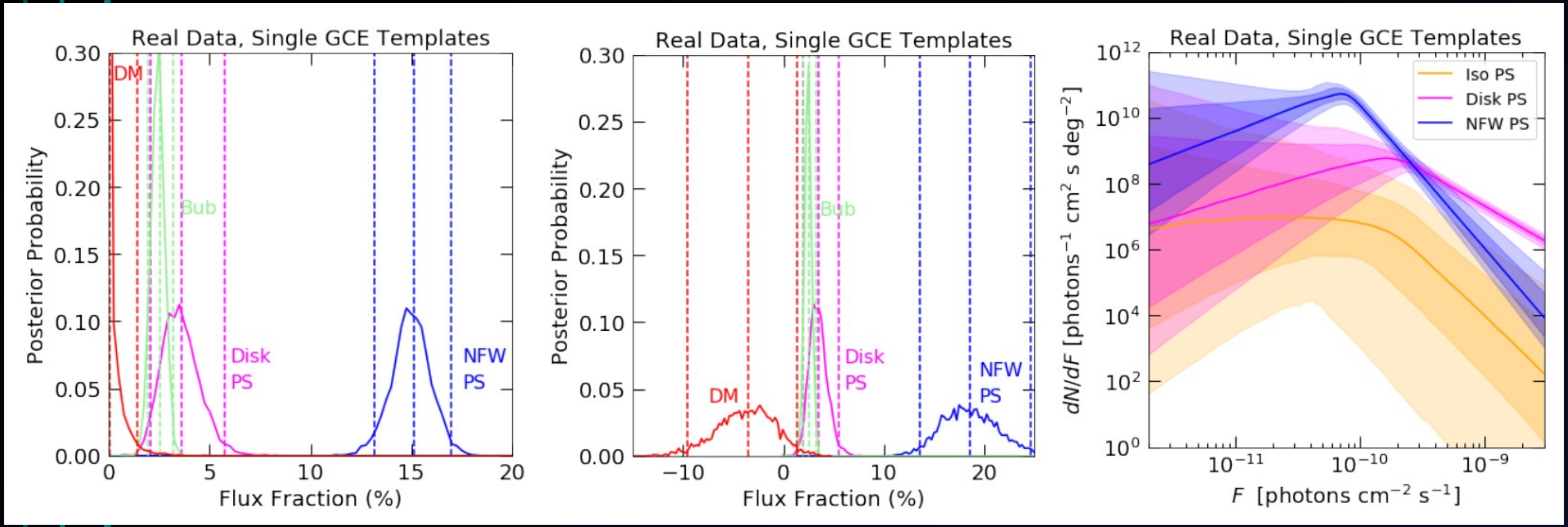
- Analyze it with one set of NFW point sources and NFW smooth, as per previous studies, compare to the real data

RL+Slatyer (PRL ‘20)
RL+Slatyer (PRD ‘20)

RL+Slatyer (PRL '20)



Real data, one excess template



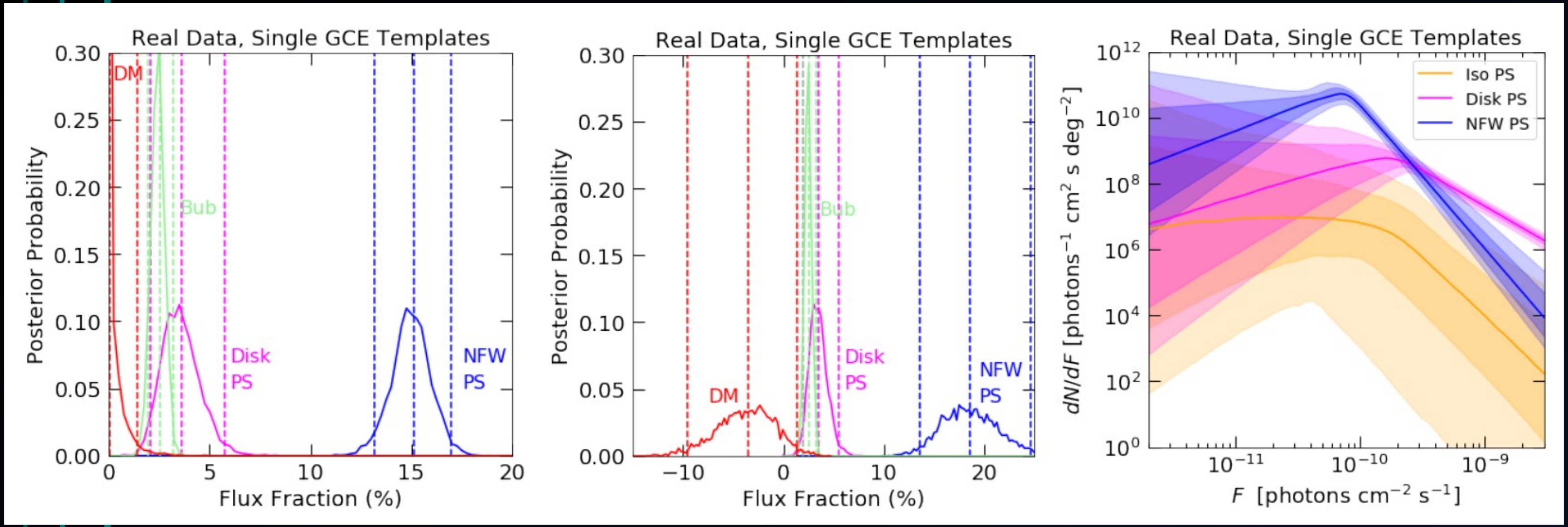
RL+Slatyer (PRL '20)

Real data, one excess template

Simulated asymmetry, analyzed with one excess template

No simulated point sources

RL+Slatyer (PRL '20)



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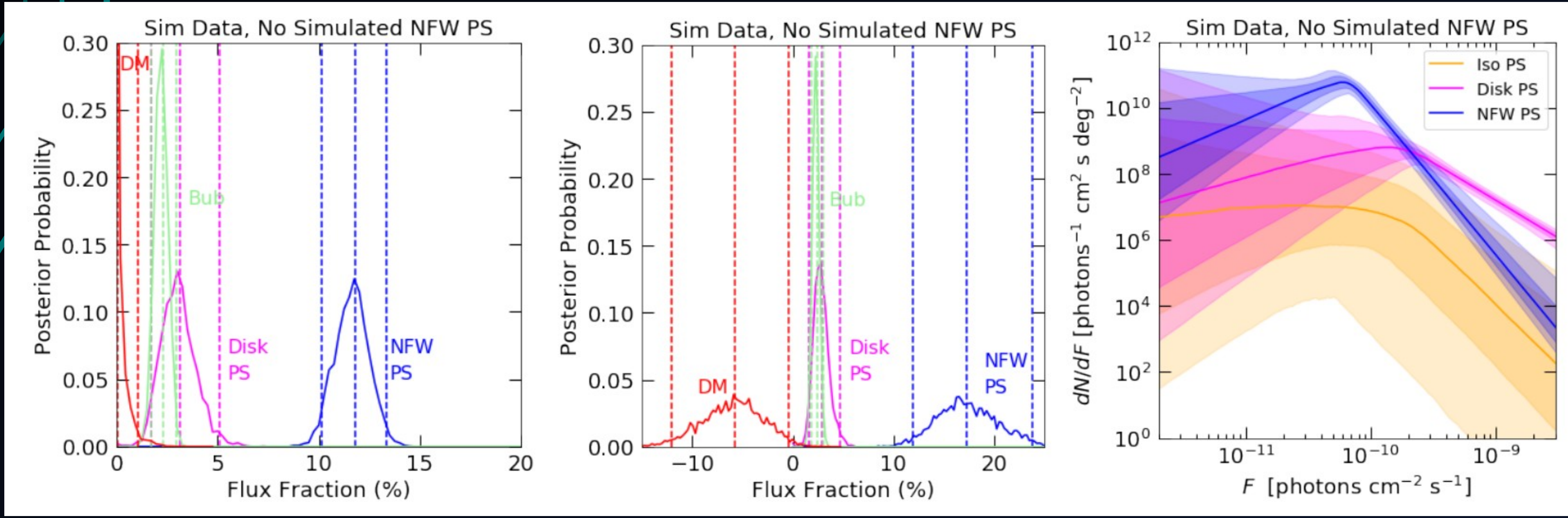

Simulated asymmetry, analyzed with one excess template

No simulated point sources

SPURIOUS POINT SOURCES IN THE GCE

- Unmodeled asymmetry leads to a spurious point source signal as the GCE
  Behavior reproduced in detail in simulations

- More broadly, **any** mismodeling might cause a spurious point source signal:
  - An incorrect model leads to increased variance relative to the data
  - Increased variance is also a feature of a point source signal!
  - Thus, variance from mismodeling can be misattributed to variance from point sources (when they don't actually exist)

RL+Slatyer (PRL '20)
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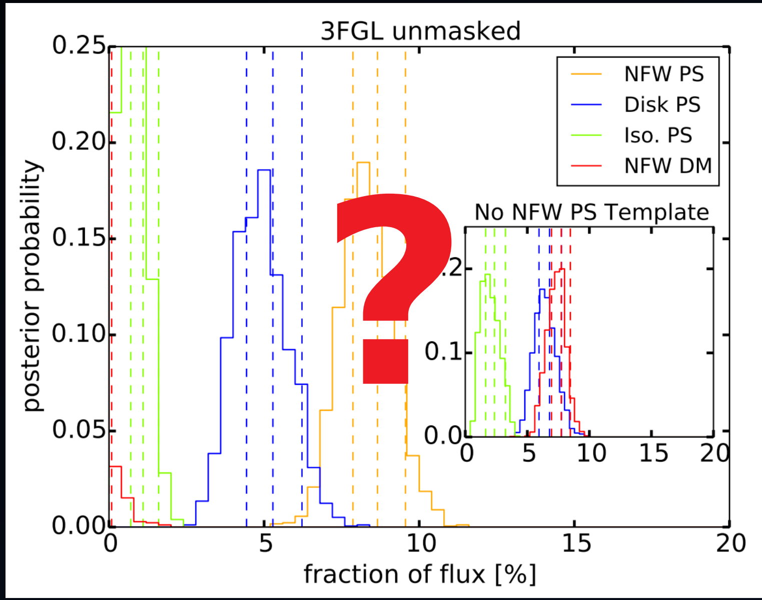
Systematics still not well enough controlled:

Claimed point source evidence for the GCE is not robust

RL+Slatyer (PRL '20)
RL+Slatyer (PRD '20)

EVIDENCE FOR POINT SOURCES AT THE GALACTIC CENTER



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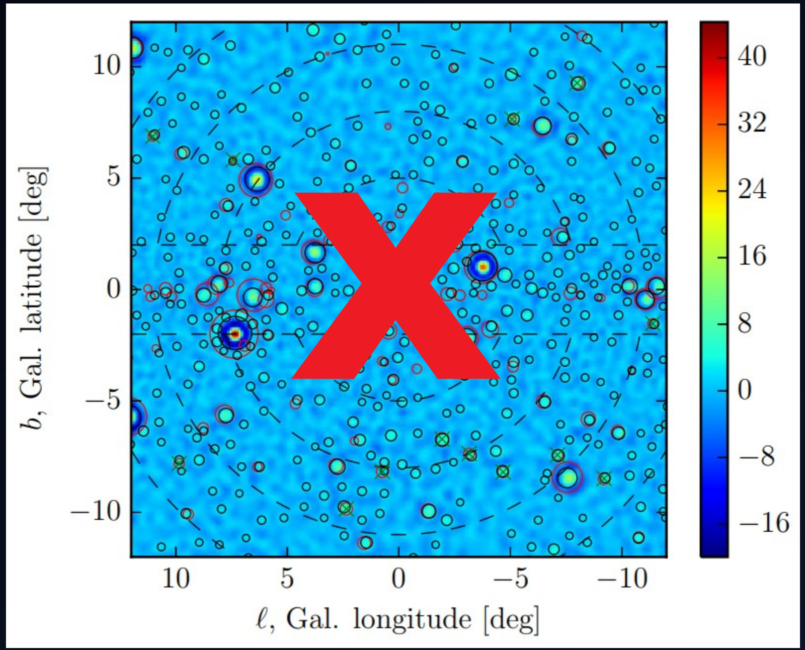

Bartels, Krishnamurthy, Weniger (PRL '15)

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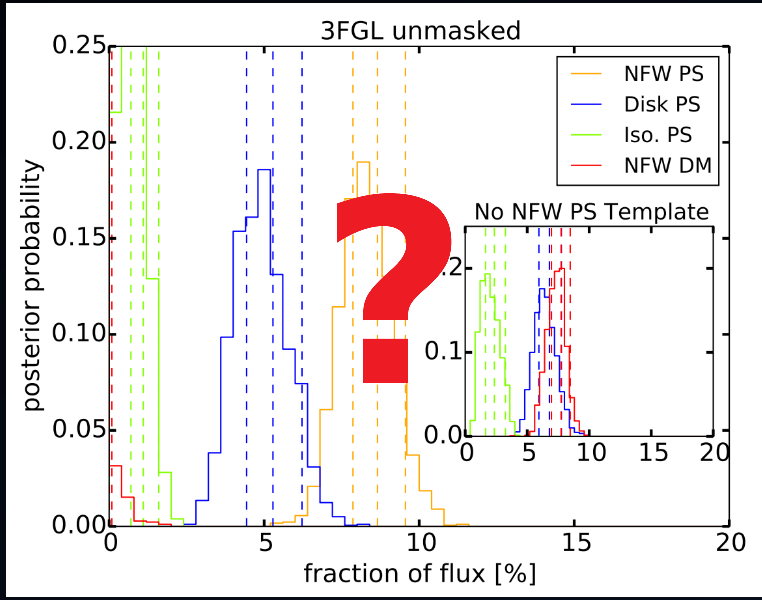

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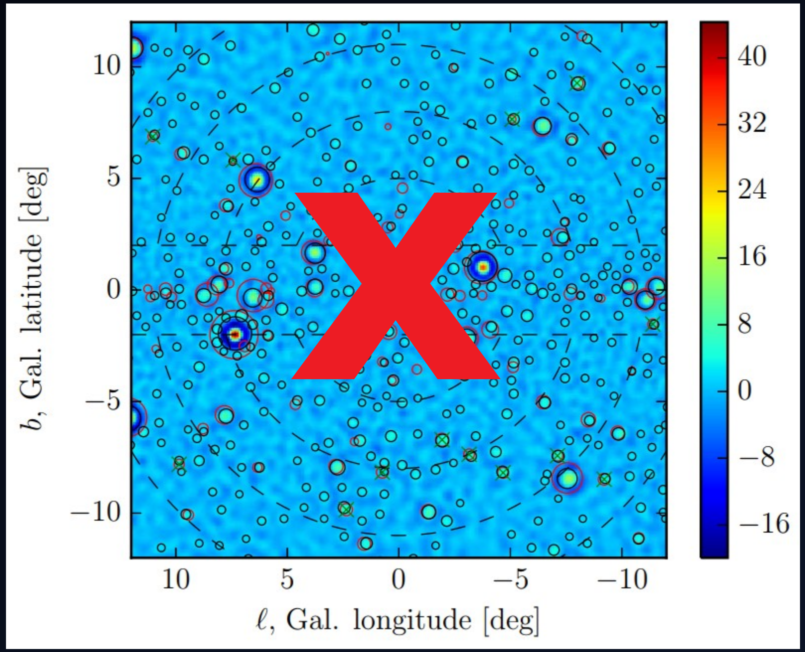


Bartels, Krishnamurthy, Weniger (PRL ’15)

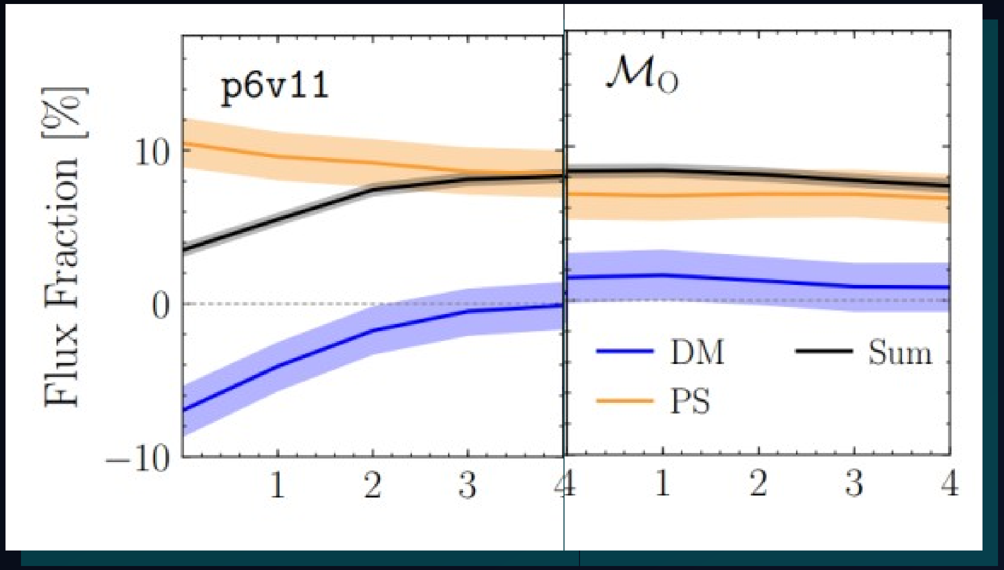
Challenged
RL+Slatyer (PRL ‘19)

Shown not currently robust
RL+Slatyer (PRL ‘20)
RL+Slatyer (PRD ‘20)

Shown these point sources are not bulk of excess
Zhong, McDermott, Cholis, Fox (PRL‘19)

GCE: EVEN MORE RECENT DEVELOPMENTS

- Dark matter injection test issue shown indeed likely due to diffuse mismodeling
- Improved diffuse models: new model + spherical harmonics
- Point source preference robust to these specific variations and diffuse models



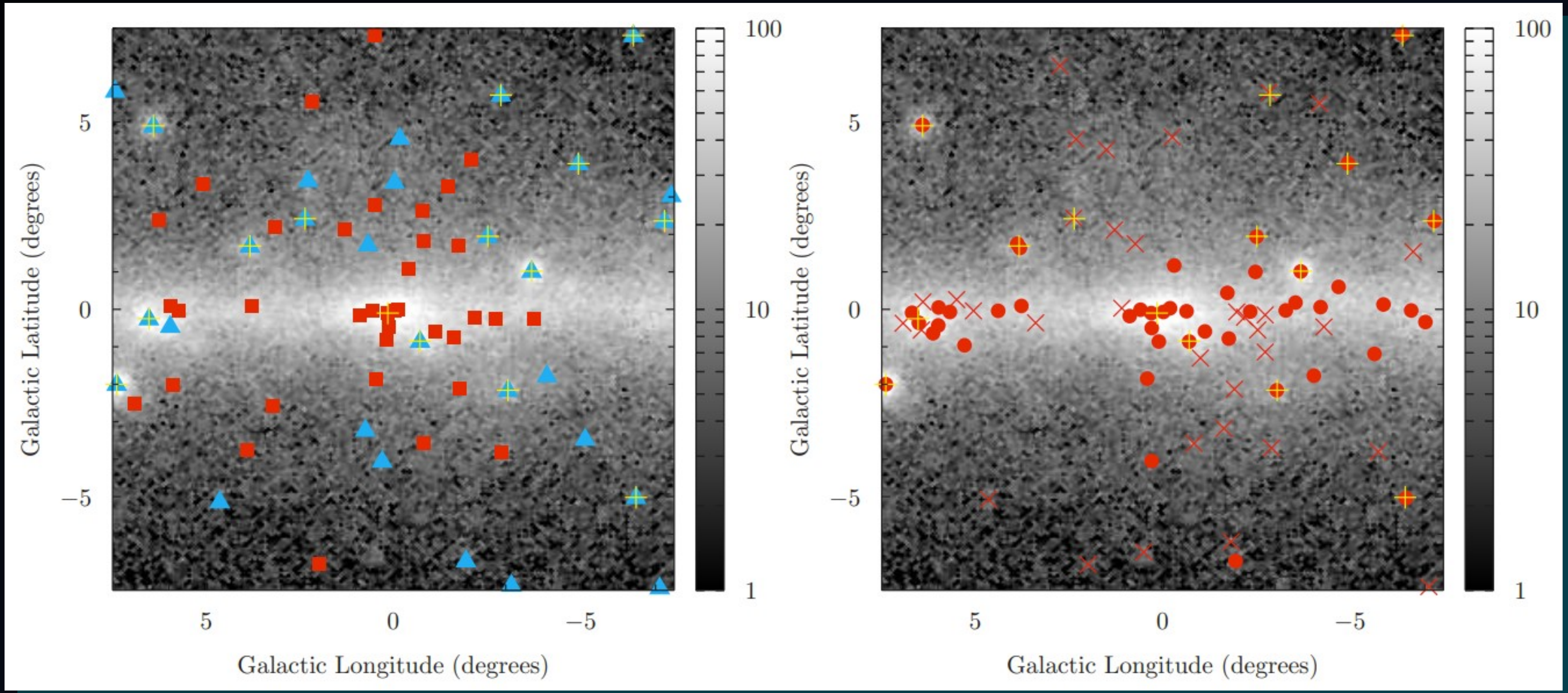
Buschmann+, '20

SYSTEMATICS: WHAT IS GOING ON?

Rebecca Leane

SYSTEMATICS: POINT SOURCE ID?

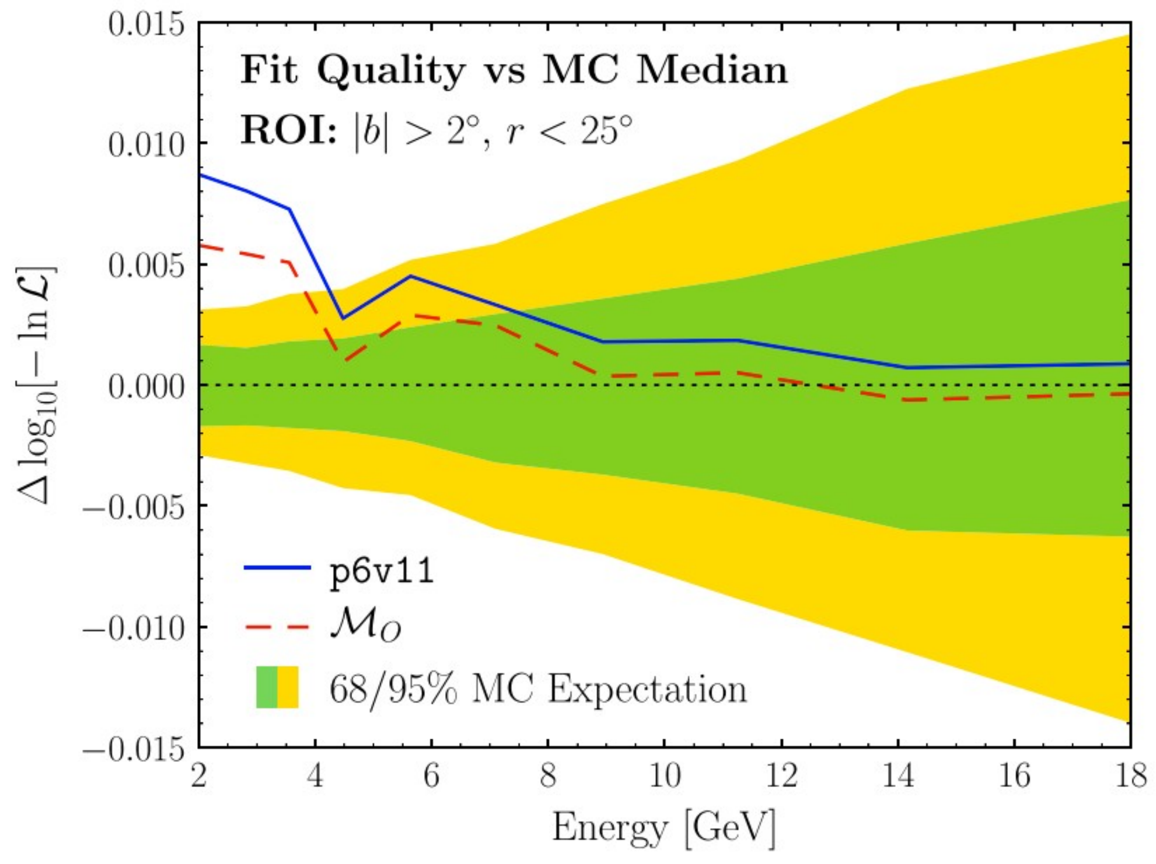
Fermi Collaboration '15



Point source catalog 1 (3FGL)   Point source catalog 2 (1FIG)

Different point sources "found" in different diffuse models!

KEY POINT: ALL DIFFUSE MODELS ARE BAD

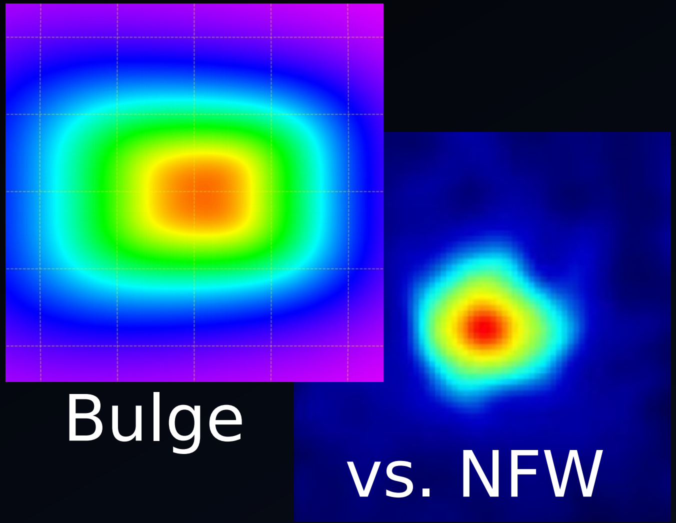


Buschmann+, '20

- Even the best diffuse models are far from good fits to the data
- Fitting to real data, and simulating based on best-fit parameters, does not return likelihoods expected within Poisson noise
- There is clearly a systematic
- Better diffuse models are key to moving forward

CURRENT PICTURE

Morphology

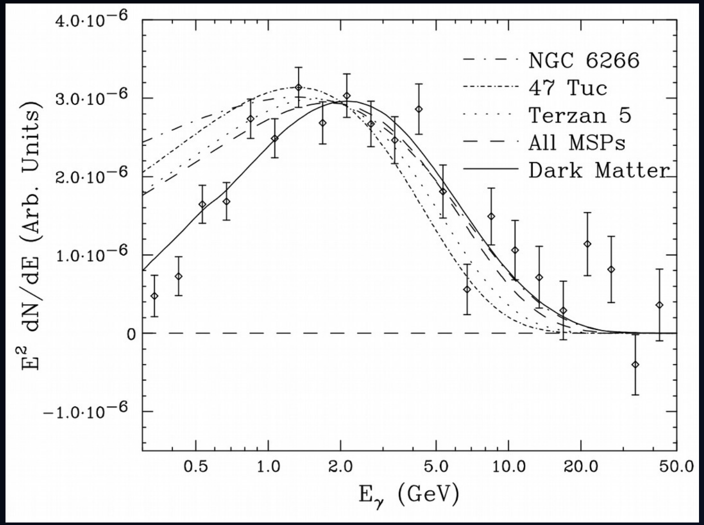


Bulge

vs. NFW

Not robustly known, but big implications

Energy Spectrum

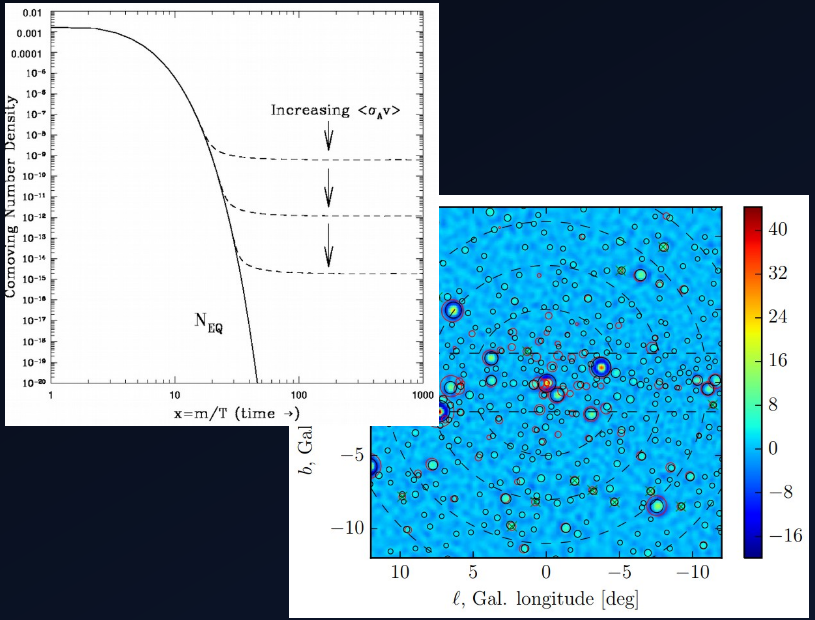


Comparable to millisecond pulsars

Can be well fit with DM annihilating to hadrons

Intensity

Well-explained by DM (Predicted by thermal relic cross section)



Tension for pulsars strong constraints on pulsar luminosity function

See Abazajian et al '20

CURRENT PICTURE

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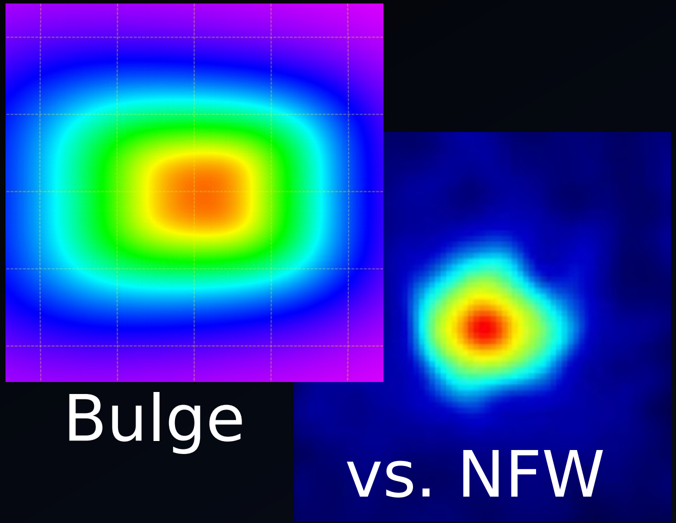

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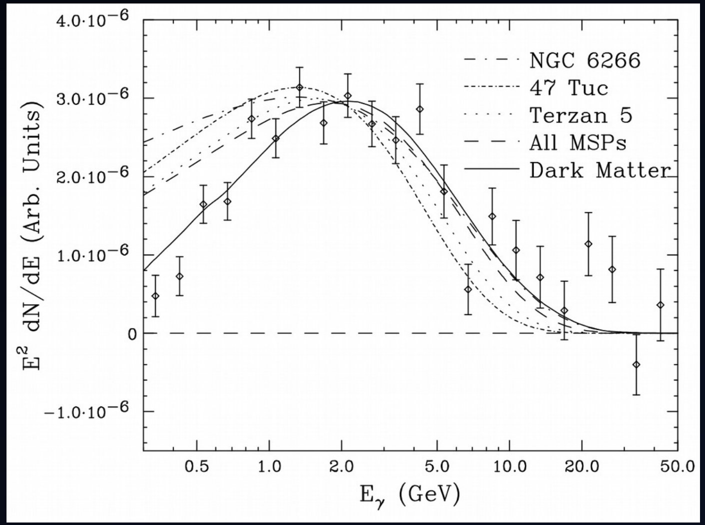

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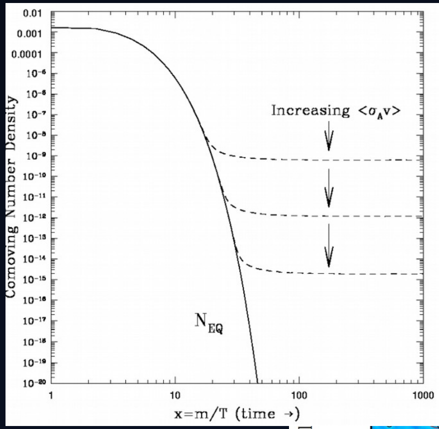

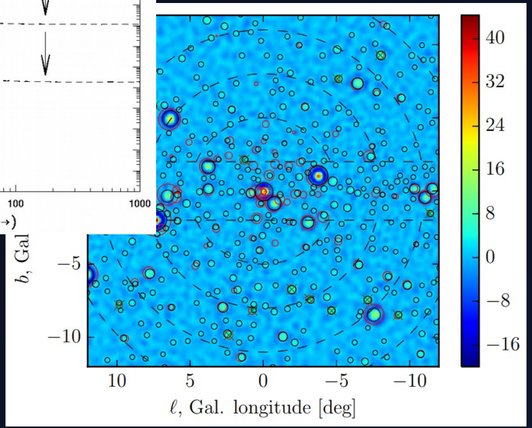

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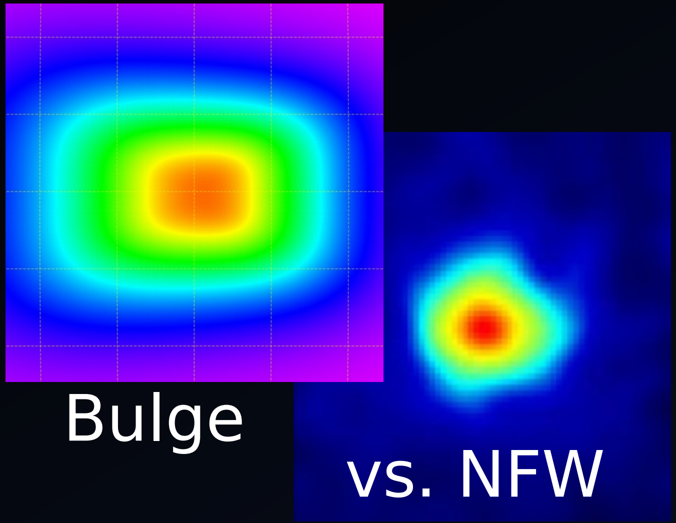

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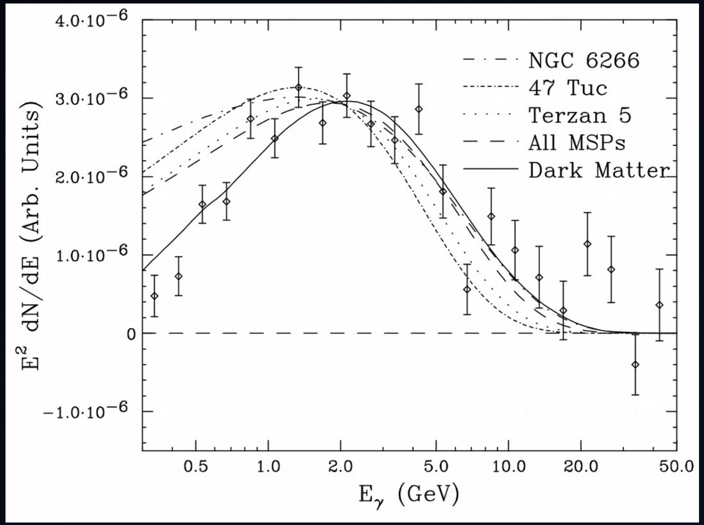

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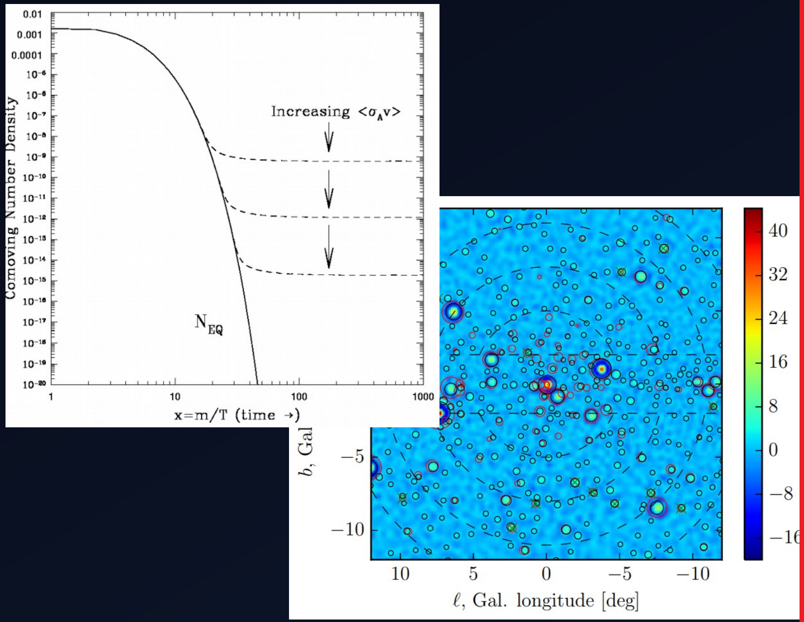


Tension for pulsars
strong constraints on
pulsar luminosity function

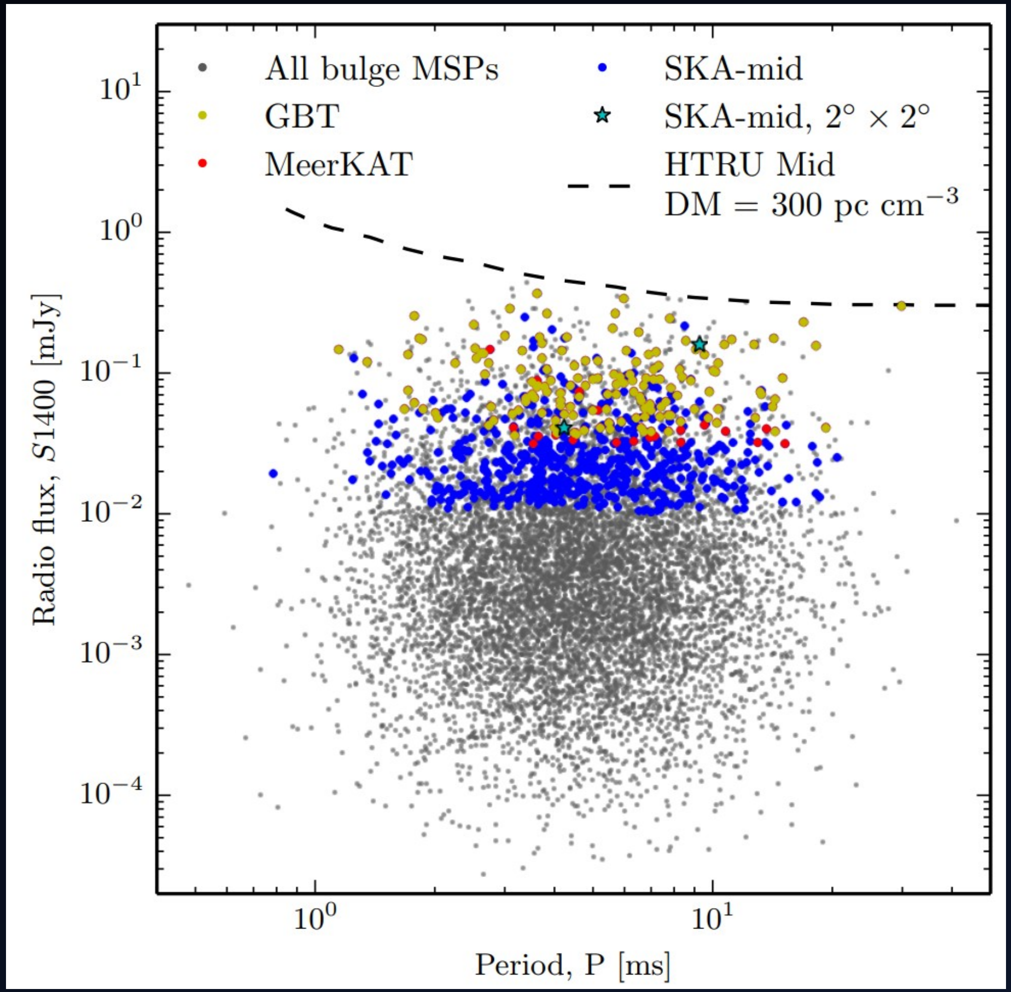
MOVING FORWARD:

DARK MATTER vs PULSARS

Rebecca Leane

PULSARS?

- Future detection of radio emission from pulsars by MeerKat and SKA

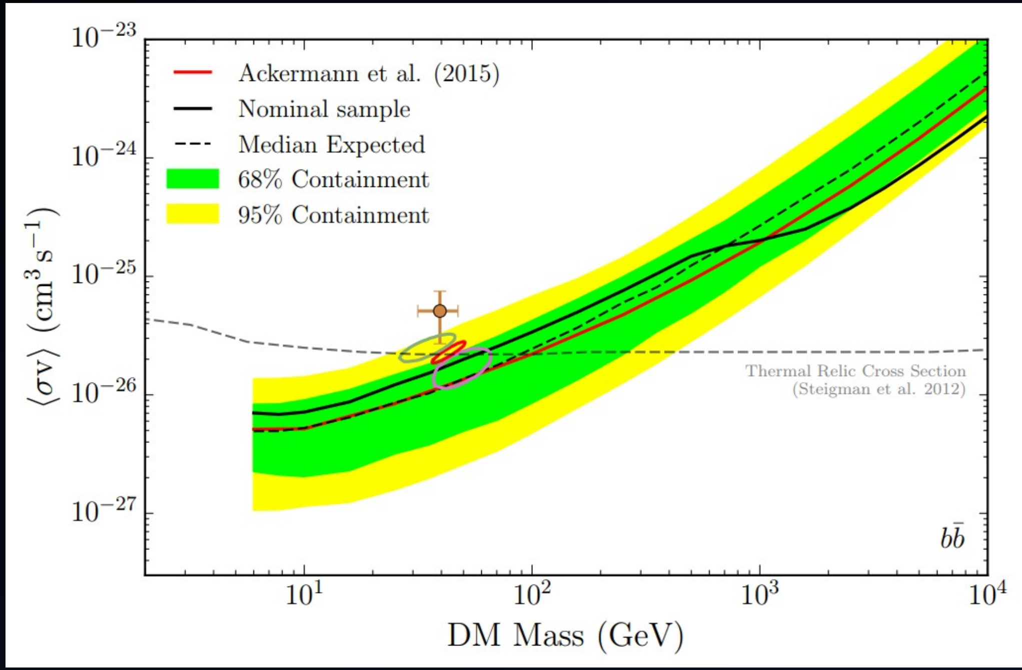


Calore+, ‘15

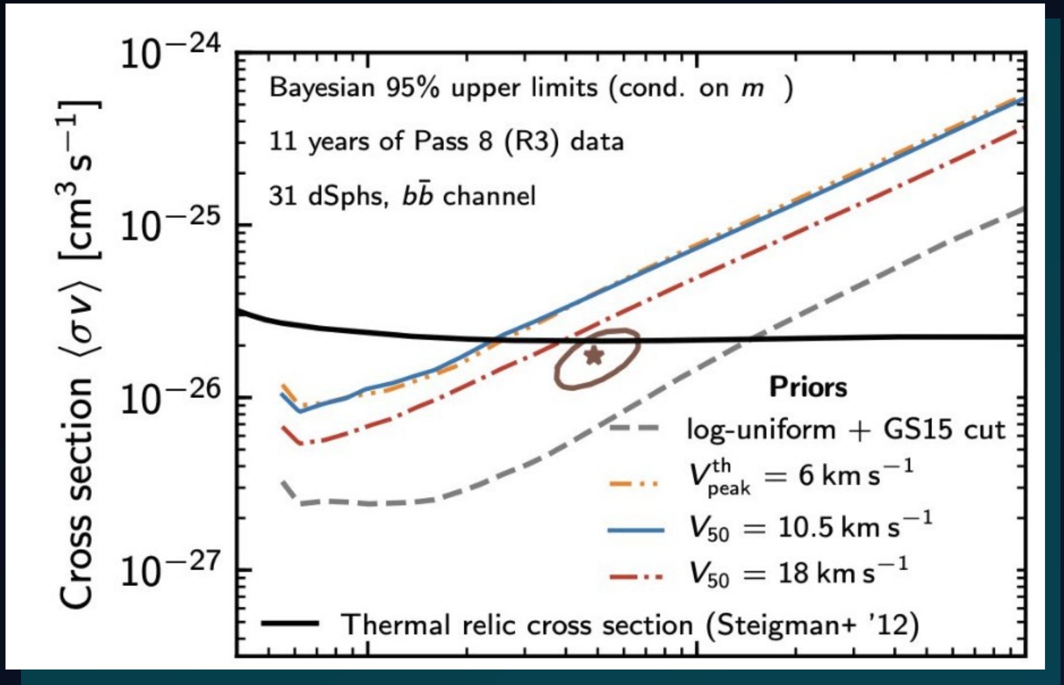
DARK MATTER: WANT A SIGNAL ELSEWHERE

- Dwarf spheroidal observations ideal
- No tension with GCE at the moment, though if the GCE really is DM, signal likely should appear soon

Ando+, ‘20



Ackermann+, ‘16

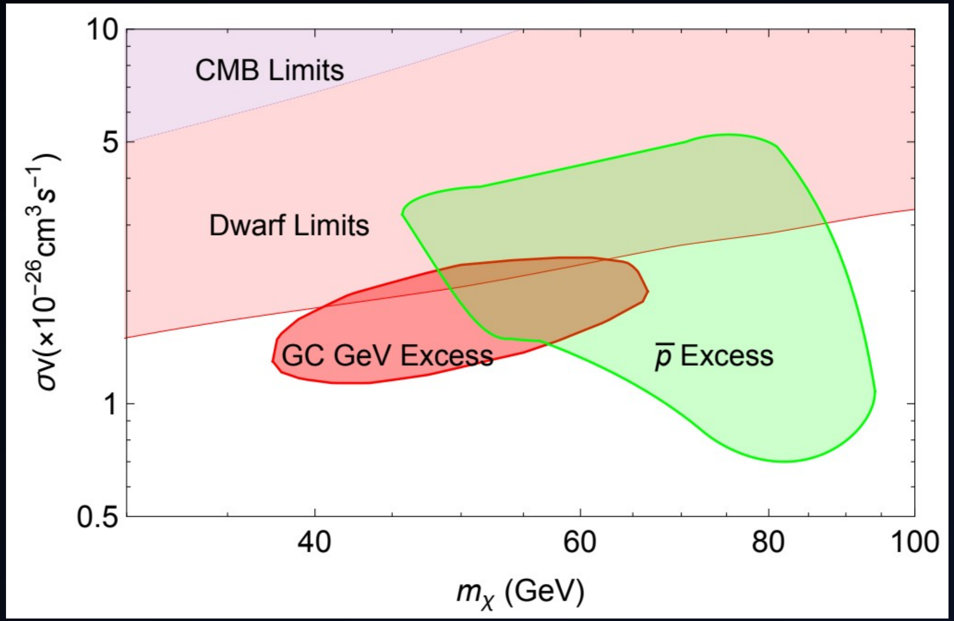


DM density uncertainties weaken limits further

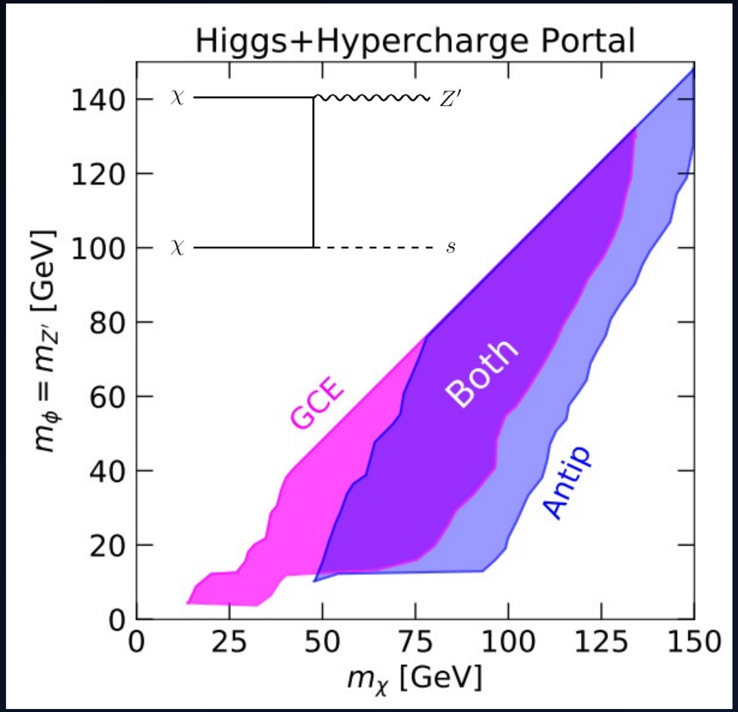
Rebecca Leane

SIGNAL ALREADY ELSEWHERE?

- Antiproton excess measured by cosmic-ray experiment AMS overlaps with GCE, though potentially only systematics
- Can be accommodated by fairly minimal models, not ruled out by collider or direct detection constraints



Cholis+, ‘19



Hooper, **RL**, Tsai, Wegsman, Witte ‘19

OTHER AVENUES

- Energy spectrum: systematics large for Fermi below a GeV, which is where pulsars and dark matter differ most!
  - Measurements with MeV gamma-ray telescopes can shed light
- Machine learning: List+'20 finds smooth GCE preference
- Better measurements of dark matter density with Gaia
- Better understanding of pulsar populations
- Better diffuse models!

SUMMARY

- Excess firmly detected, signal origin is unknown – controversial signal!

- Exciting possibility: we are seeing evidence for annihilating dark matter
  - Main arguments for: signal has consistent intensity, spectrum, and potentially morphology
  - Argument against: potentially morphology, though systematics unclear

- Leading alternative explanation: pulsars
  - Main argument for: energy spectrum looks consistent, potentially morphology
  - Arguments against: where are they, and their x-ray binaries? We don't see them in any wavelength. How do you get such a large number of them in the galactic center?

- Previous 2015 point source evidence has been challenged
  - Non-poissonian template fitting results have substantial uncontrolled systematics
  - Unmodeled asymmetries, or mismodeling more broadly might produce spurious point source signals
  - Updated wavelet study: previously found point sources actually cannot be the bulk of the excess

- Lots of ways forward: complementary searches for both dark matter and pulsars, +improving modeling!

The puzzle continues...

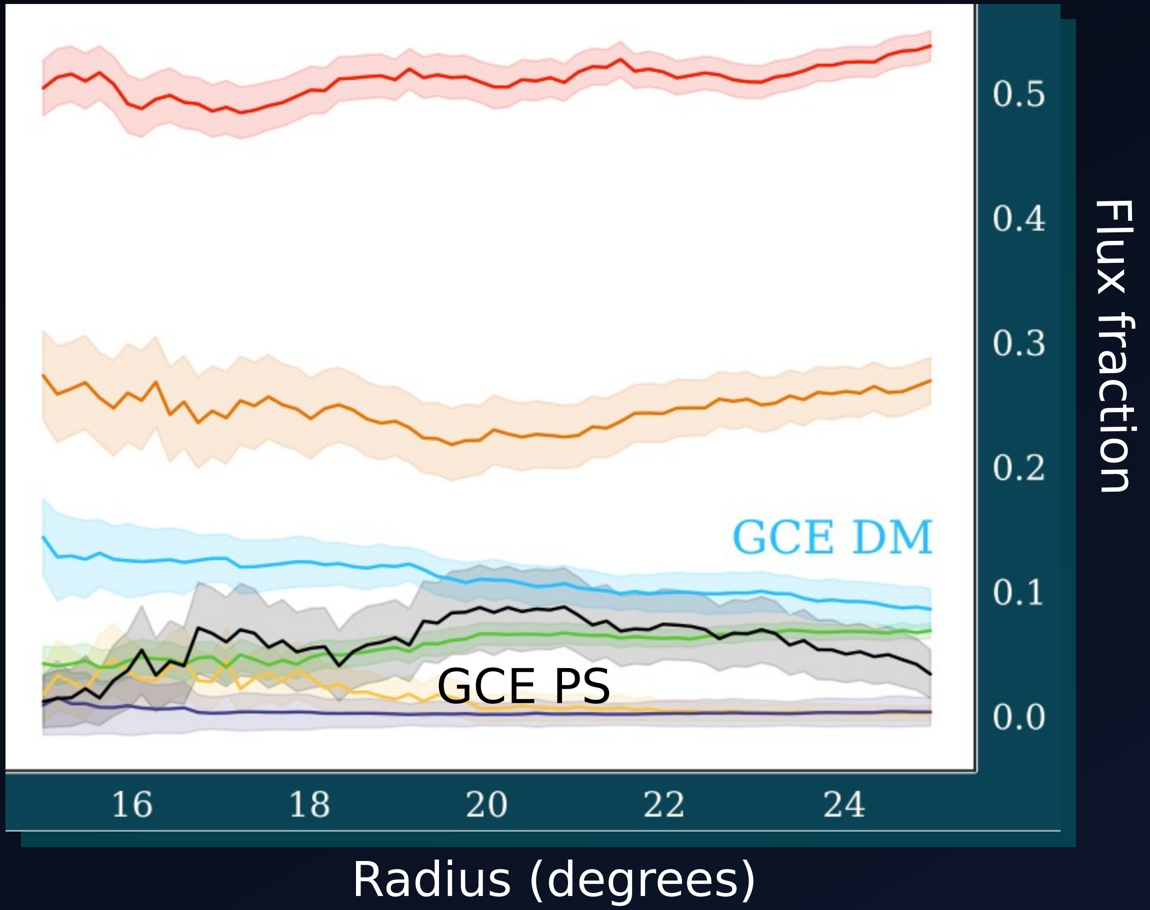
EXTRA SLIDES

Rebecca Leane

ALTERNATE FITTING METHOD

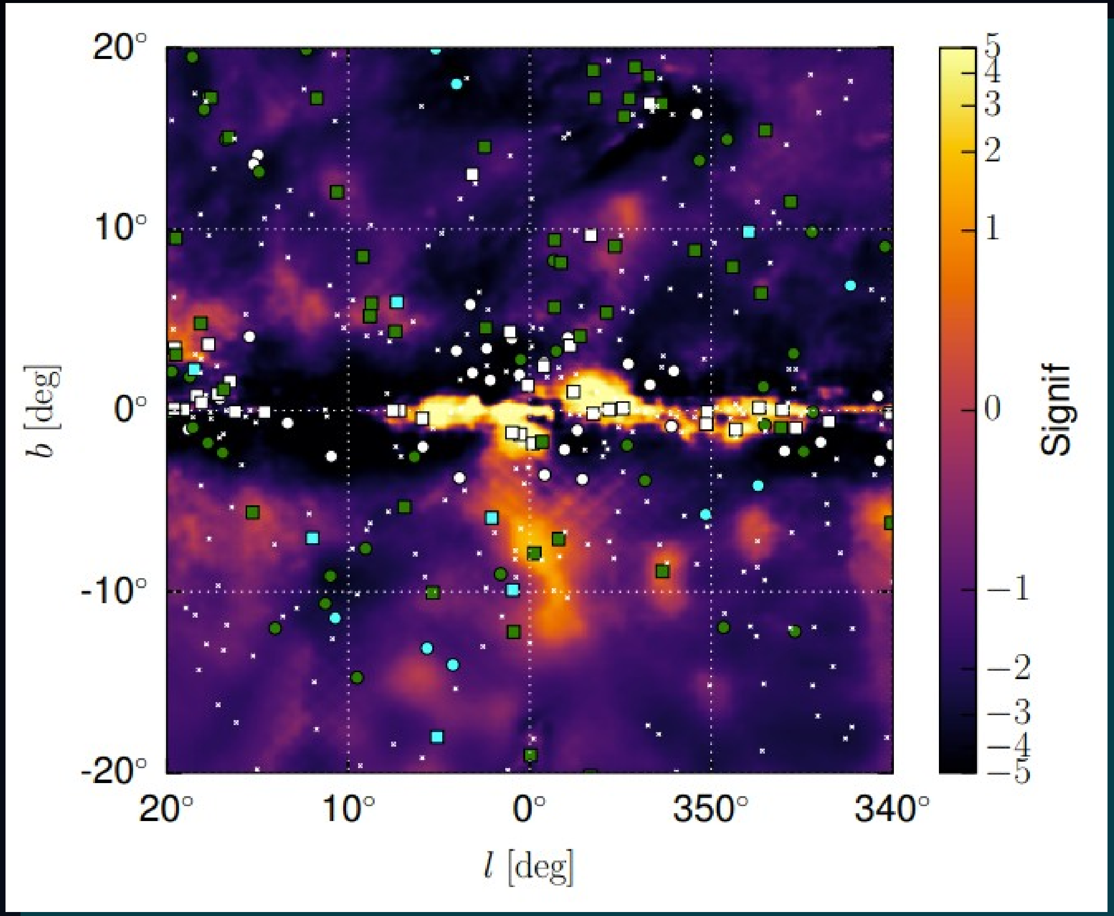
- Train neutral networks on simulated datasets
- Finds same GCE flux fraction as non-Poissonian template fitting, but finds smooth GCE!
- Complementary handle on systematics

List+, ‘20



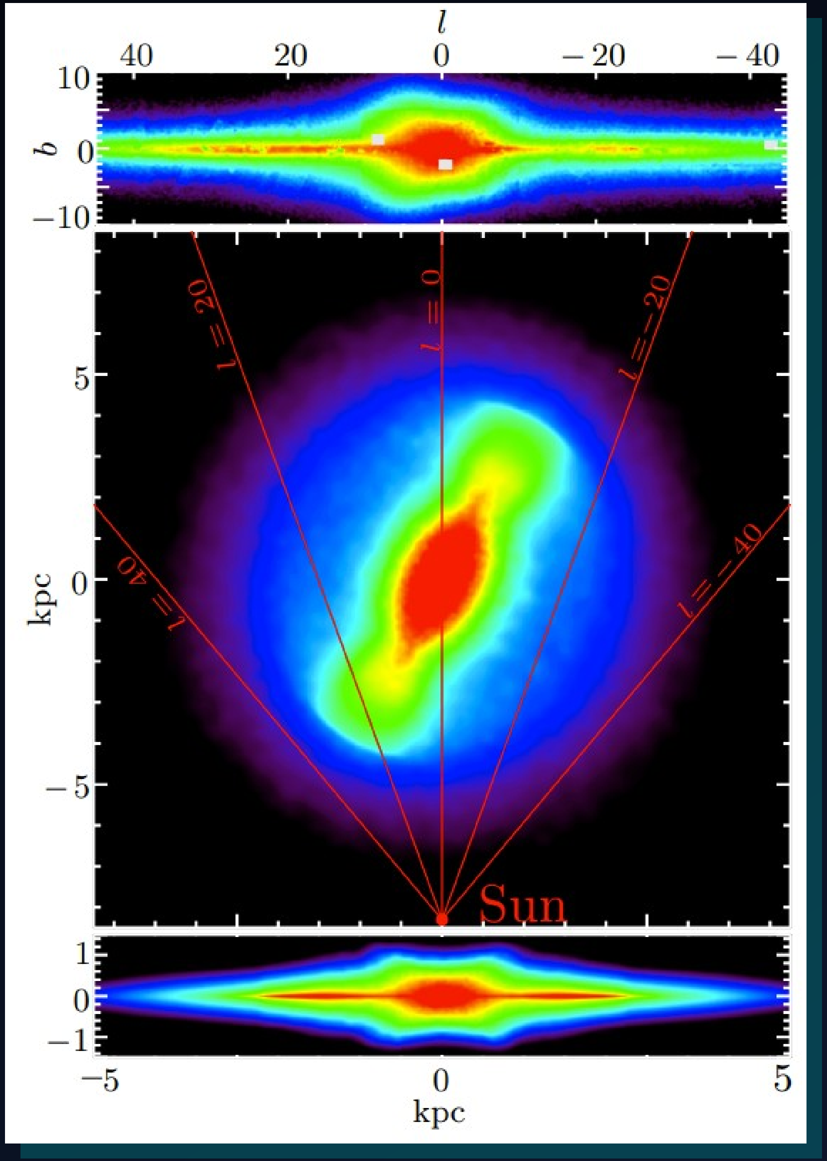
SYSTEMATICS: POINT SOURCE ID?

Fermi Collaboration '17



White dots show point sources that are detected at 7 sigma in one model, but not detected in the other

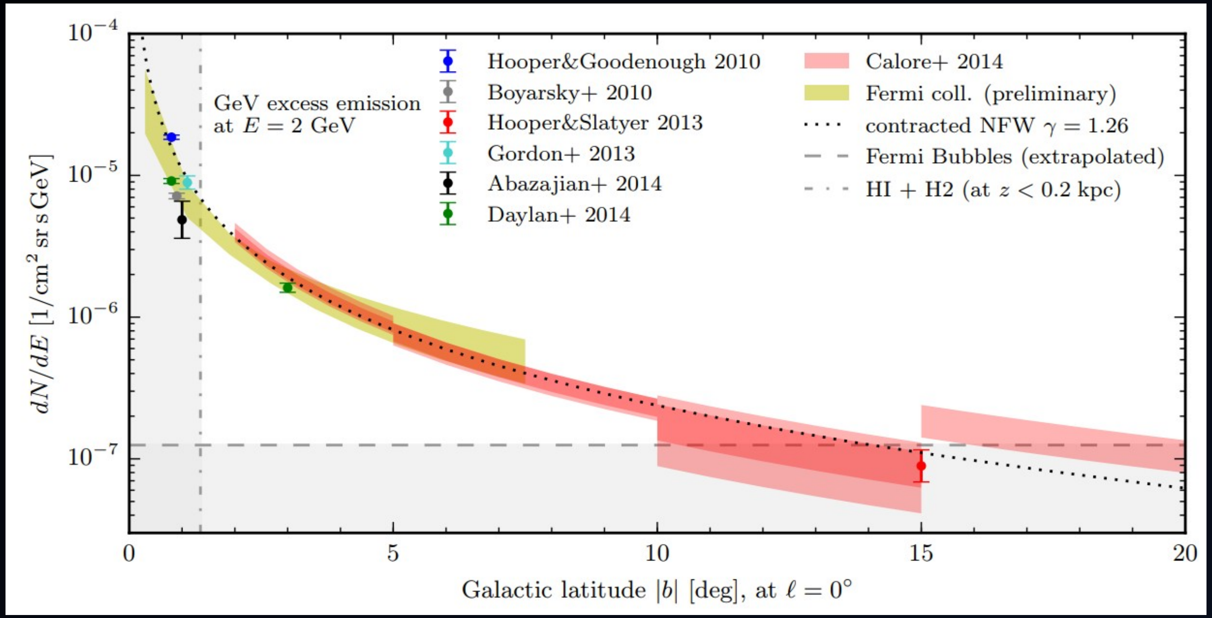
BULGE SHAPE

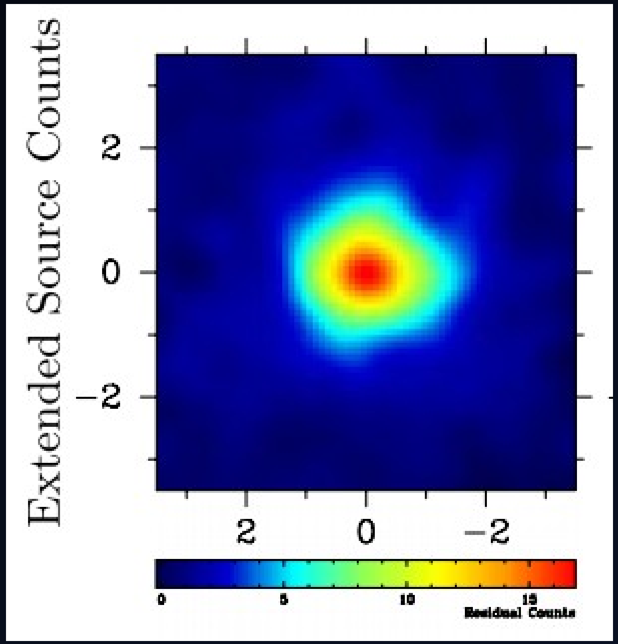


Bland-Hawthorn, Ortwin Gerhard ‘17

MORPHOLOGY

Calore et al '14



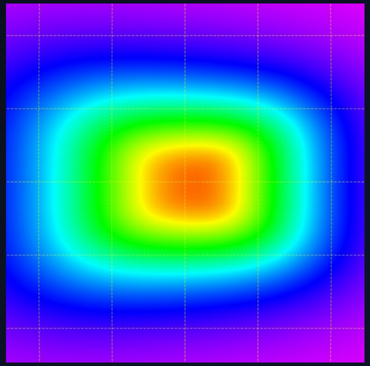


Abazajian+ Kaplinghat '12

Spherically symmetric around Galactic Center

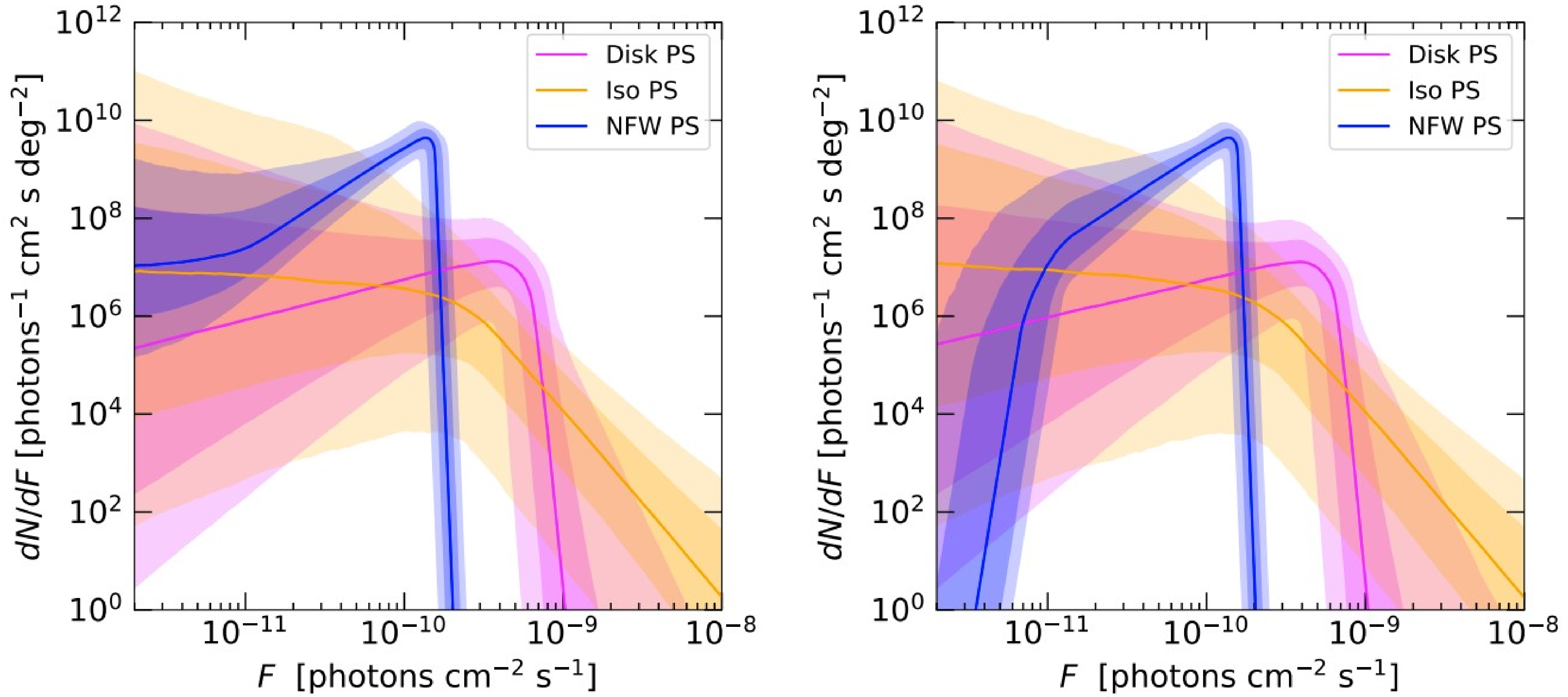
Scales like r $^{-2.4}$ extending out to around 10°, roughly fits standard dark matter (NFW) profile

Hooper+Slatyer '13

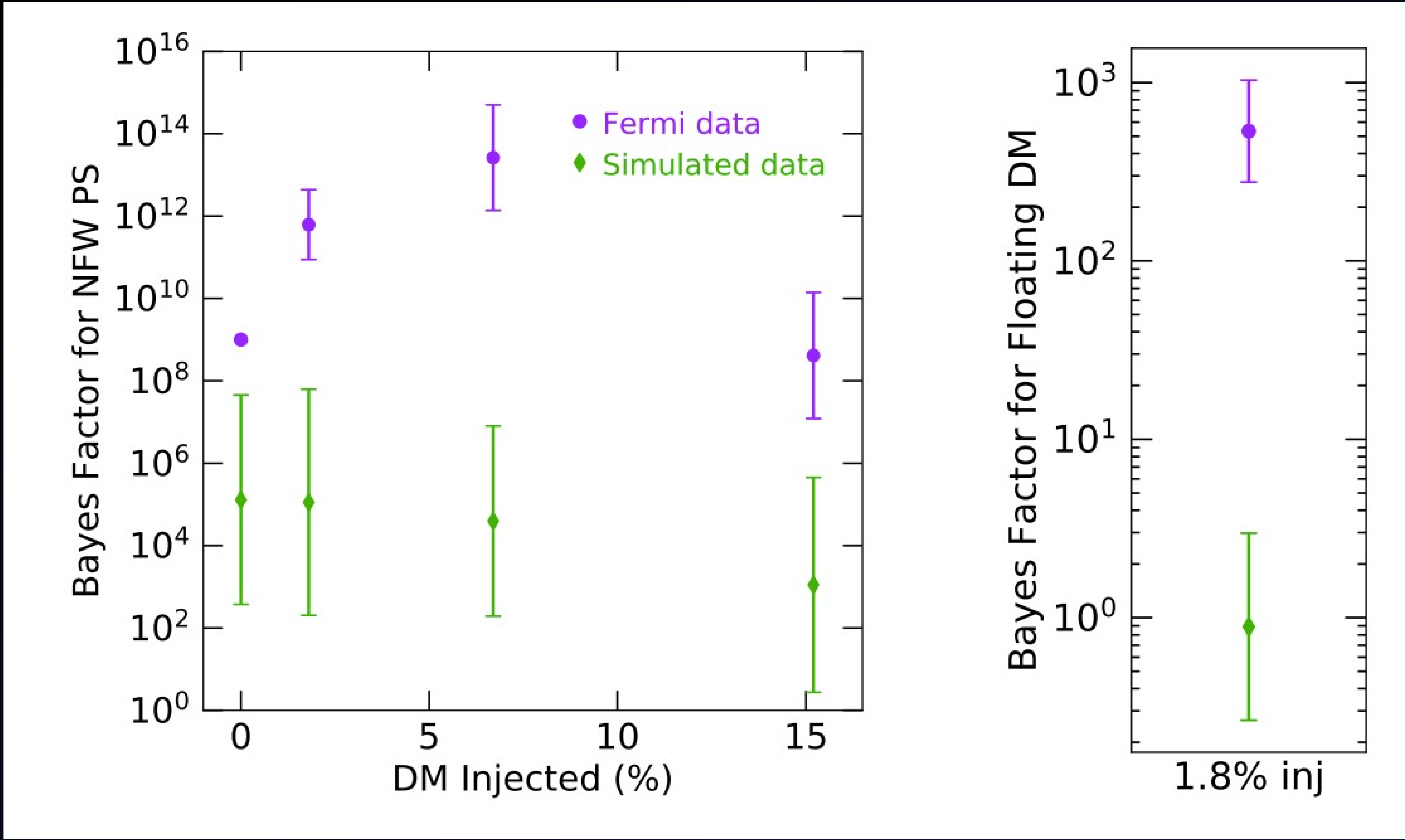


More recent studies find bulge preference

Macias '16
Bartels '17
Macias '19
Abazajian '20

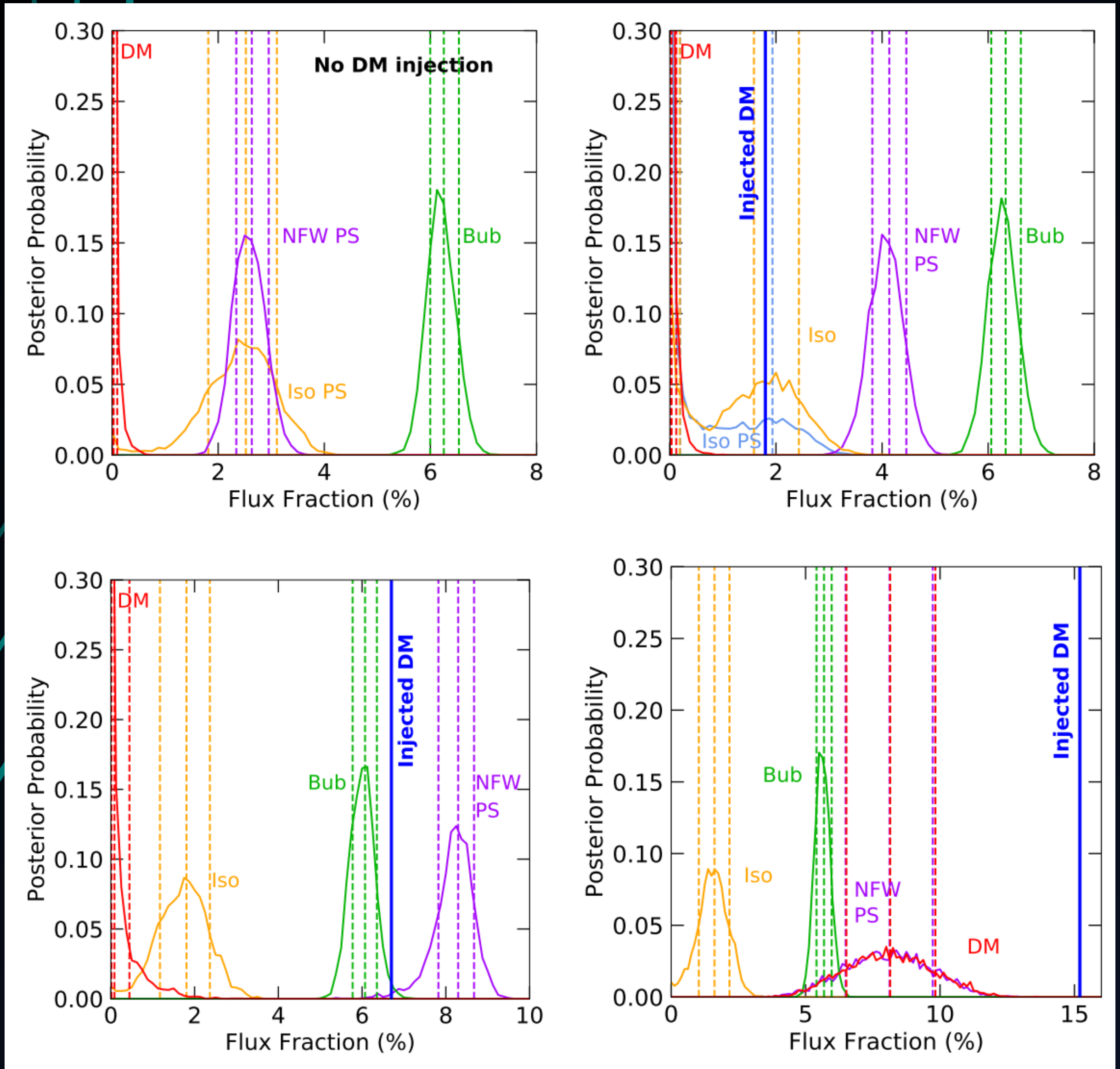


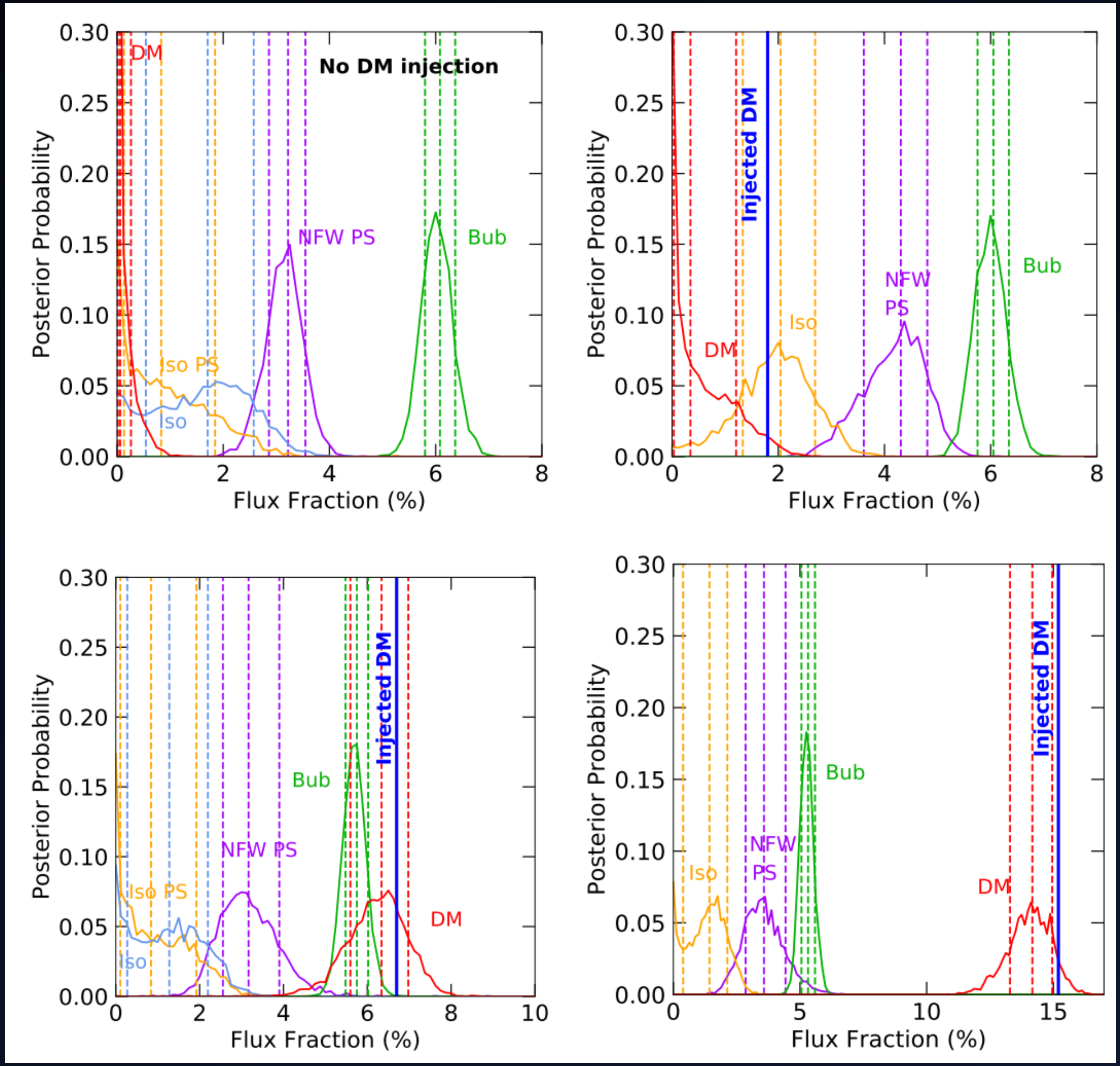
Disk PS
Iso PS
NFW PS
dN/dF [photons⁻¹ cm² s deg⁻²]
F [photons cm⁻² s⁻¹]
Disk PS
Iso PS
NFW PS
dN/dF [photons⁻¹ cm² s deg⁻²]
F [photons cm⁻² s⁻¹]



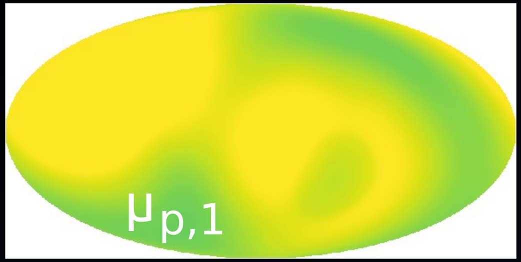
Bayes Factor for NFW PS
DM Injected (%)
Fermi data
Simulated data
Bayes Factor for Floating DM
1.8% inj

REAL DATA vs SIMULATED DATA

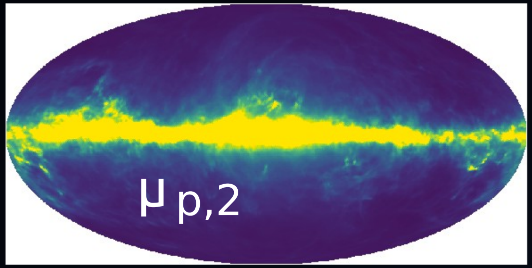




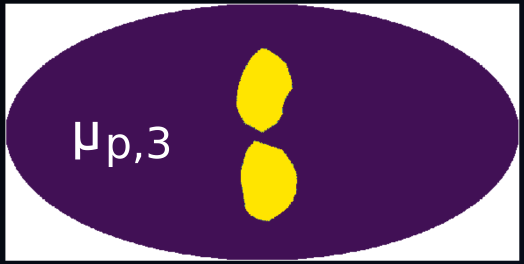
POISSON TEMPLATE FITTING



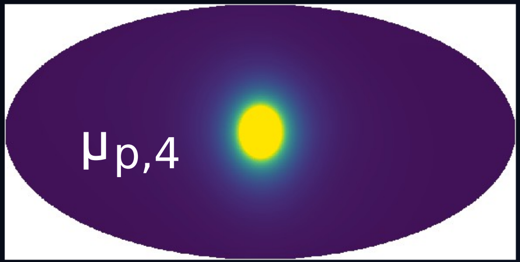
$\times \alpha_1$



$\times \alpha_2$



$\times \alpha_3$



$\times \alpha_4$

Prediction for each pixel

$$\mu_p = \sum_\ell \alpha_\ell \, \mu_{p,\ell}$$

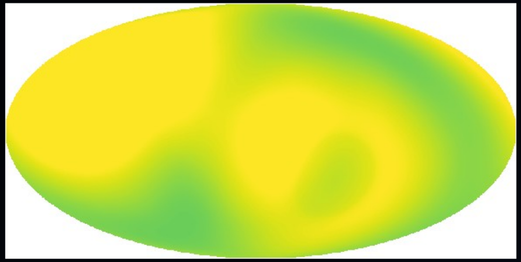
Likelihood per pixel is a Poisson distribution

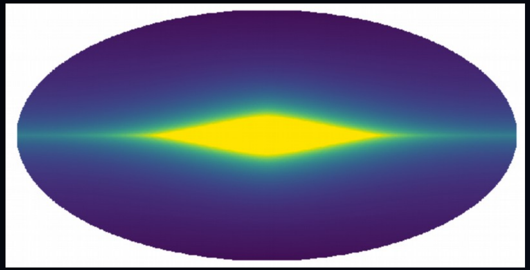
$$p_{n_p}^{(p)}(\boldsymbol{\theta}) = \frac{\mu_p^{n_p}(\boldsymbol{\theta})}{n_p!} e^{-\mu_p(\boldsymbol{\theta})}$$

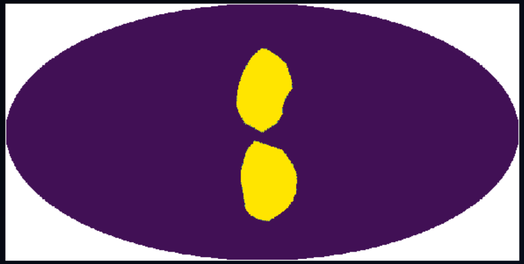
Total likelihood is given by product of Poisson likelihoods for each pixel

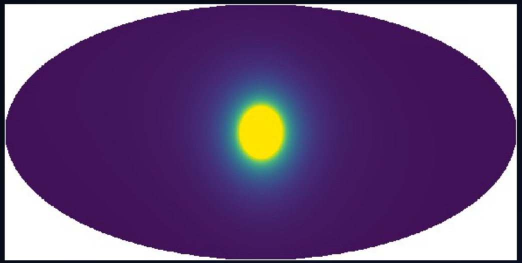
$$p(d|\boldsymbol{\theta}, \mathcal{M}) = \prod_p p_{n_p}^{(p)}(\boldsymbol{\theta})$$

NON-POISSON TEMPLATE FITTING





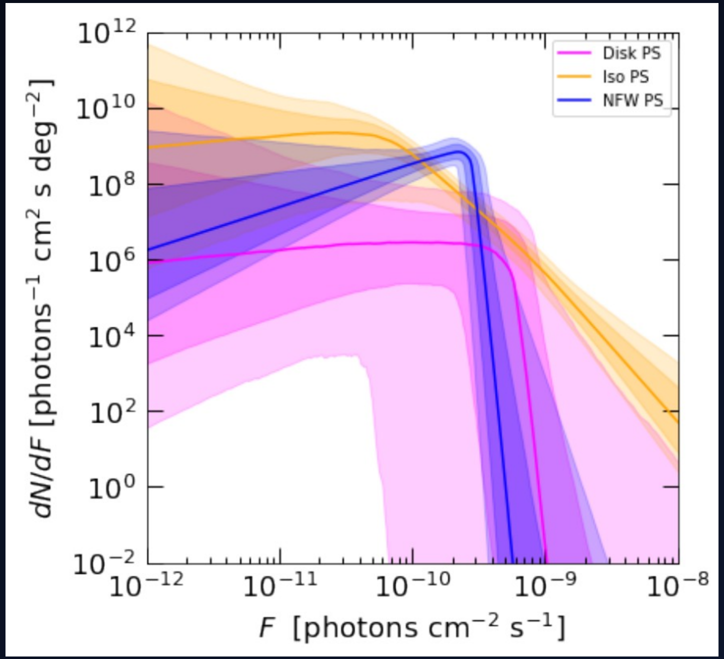




Photon count distribution has an additional dependence on a pixel-dependent PS source-count distribution. This can be modelled by a broken power law:

$$\frac{dN_p(S)}{dS} = A_p \begin{cases} \left(\frac{S}{S_b}\right)^{-n_1} & S \geq S_b \\ \left(\frac{S}{S_b}\right)^{-n_2} & S < S_b \end{cases}$$

3 additional degrees of freedom:
indices n1 and n2, and break Sb



NON-POISSON TEMPLATE FITTING

Predictions for each pixel in terms of generating functions, incorporates both Poisson and non-Poisson templates.

$$P_k^{(p)} = \frac{1}{k!} \frac{d^k \mathcal{P}^{(p)}(t)}{dt^k}\bigg|_{t=0}$$

Poisson generating function:

$$\mathcal{P}_\ell^{(p)}(t) = e^{\mu_{p,\ell}(t-1)}$$

Non-Poisson generating function:

$$\mathcal{P}_{\mathrm{NP}}(t;\boldsymbol{\theta}) = \prod_p \exp\left[\sum_{m=1}^{\infty} x_{p,m}(\boldsymbol{\theta})(t^m - 1)\right]$$

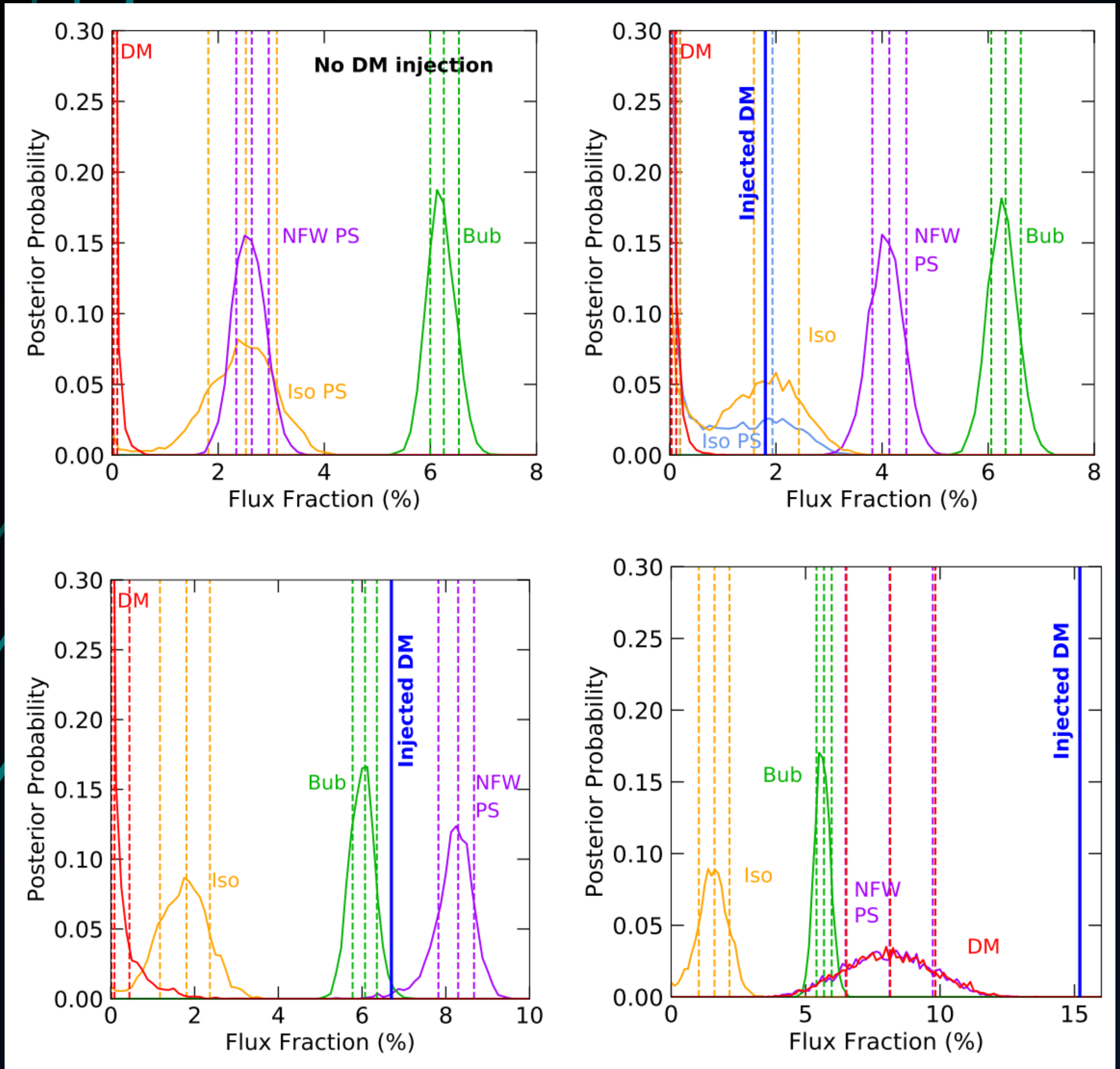
Expected number of m-photon sources is

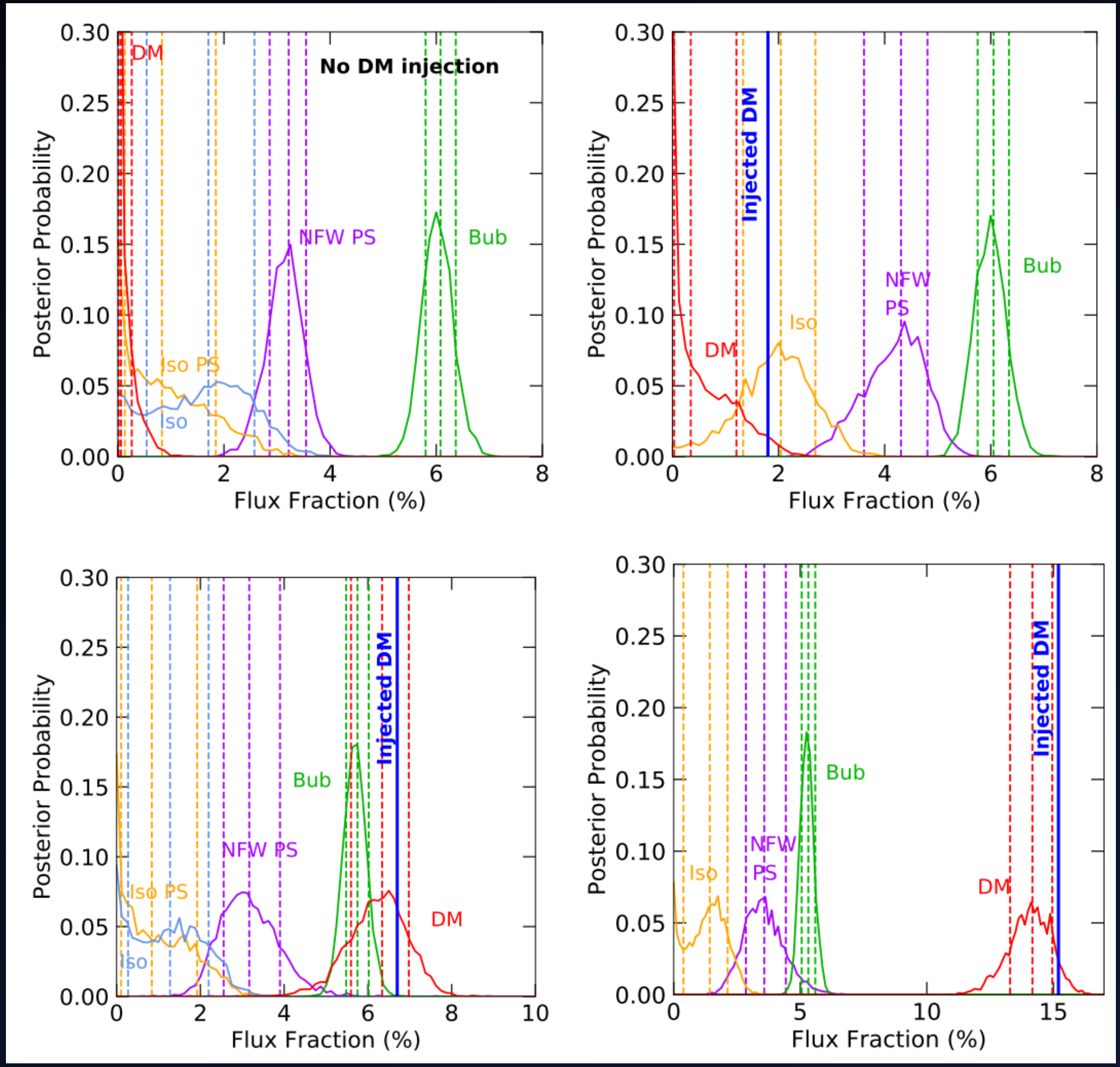
$$x_{p,m}(\boldsymbol{\theta}) = \underbrace{\int_0^\infty dS \frac{dN_p}{dS}(S;\boldsymbol{\theta})}_{\text{SCF}} \underbrace{\int_0^1 df\, \rho(f)}_{\text{PSF}} \frac{(fS)^m}{m!} e^{-fS}$$

probability seeing m photons when fS is expectation

Malyshev+Hogg ‘11
Lee+Lisanti+Safdi ‘15

REAL DATA vs SIMULATED DATA





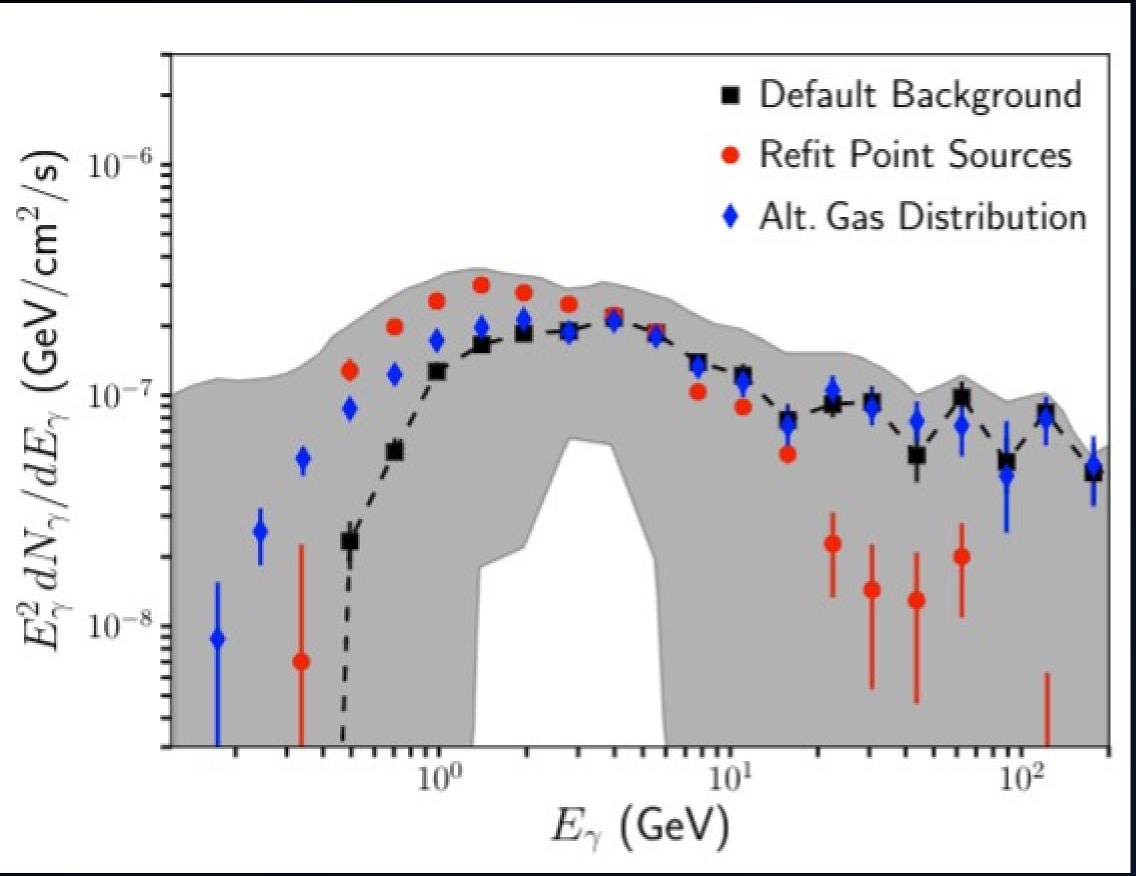
NPTF TOOLS

- Analyze data using NPTFit
  (Mishra-Sharma, Rodd, Safdi ‘16)
  github.com/bsafdi/NPTFit

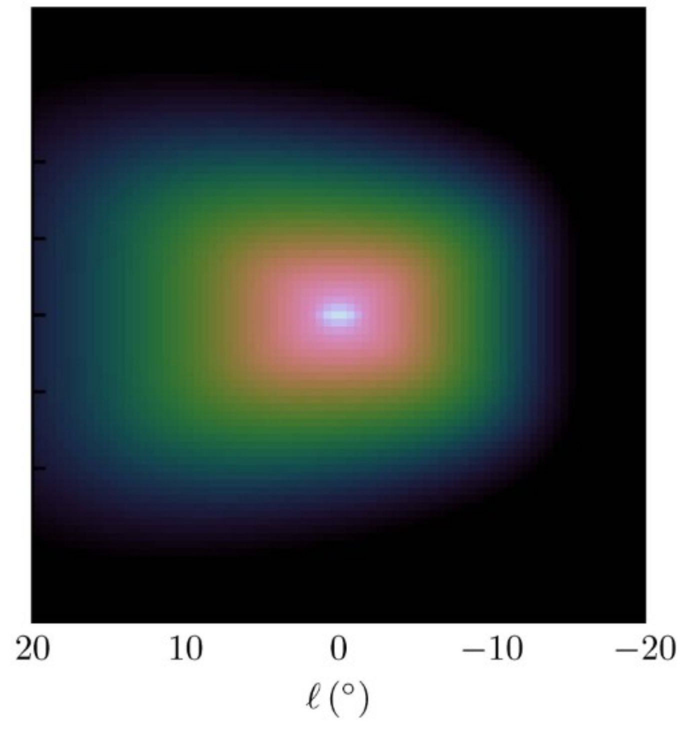
- Simulate NP data using NPTFit-Sim (Rodd, Toomey)
  github.com/nrodd/NPTFit-Sim

THEORY IDEAS?

- Looking in individual ROIs
- Better understanding diffuse models
- Studying individual energy bins
- Complementary methods: SKYFACT, wavelet technique


Default Background
Refit Point Sources
Alt. Gas Distribution
$E_\gamma^2\, dN_\gamma/dE_\gamma$ (GeV/cm^2/s)
10^{-6}
10^{-7}
10^{-8}
10^0
10^1
10^2
E_γ (GeV)

WHAT ABOUT THE BOXY BULGE?



- Population of stars at the GC
- Unmodelled candidate could impact interpretation of the data